[COMMITTEE PRINT]

U.S. SCIENCE AND ENGINEERING EDUCATION AND MANPOWER: BACKGROUND; SUPPLY AND DEMAND; AND COMPARISON WITH JAPAN, THE SOVIET UNION, AND WEST GERMANY

REPORT

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LETTER OF TRANSMITTAL

House of Representatives,
Committee on Science and Technology,
Washington, D.C., April 19, 1983.

Hon. Don Fuqua,
Chairman, Committee on Science and Technology,
U.S. House of Representatives.

Dear Mr. Chairman: The following report is a study of the current situation in science and engineering education and manpower in the United States. The study includes a discussion of such aspects as general background, supply and demand, and international comparisons. I hope it will be useful to the Members of the Science Committee and other Members of Congress in considering legislation that affects this area.

The study is the product of the dedicated work of Mrs. Edith Fairman Cooper of the Congressional Research Service in conjunction with members of the staff of the Subcommittee on Science, Research and Technology.

I commend this study to your attention and the attention of our colleagues.

Sincerely,

Doug Walgren,
Chairman, Subcommittee on Science,
Research and Technology.

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LETTER OF SUBMITTAL

July 22, 1982

Honorable Don Fuqua
Chairman, Committee on Science
and Technology
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

I am pleased to submit this report, entitled U.S. Science and Engineering Education and Manpower: Background; Supply and Demand; and Comparison with Japan, the Soviet Union, and West Germany, which has been prepared at the request of the House Committee on Science and Technology.

The report was prepared by Mrs. Edith Fairman Cooper of the Science Policy Research Division. We believe that the report will be useful to the Committee in its continuing concerns with the problems related to the current and future conditions of the Nation's scientific and engineering education and manpower and how the U.S. situation compares with other major countries.

Sincerely,

Gilbert Gude
Director

Congressional Research Service
The Library of Congress

Washington, D.C. 20540

U.S. SCIENCE AND ENGINEERING EDUCATION AND MANPOWER: BACKGROUND; SUPPLY AND DEMAND; AND COMPARISON WITH JAPAN, THE SOVIET UNION, AND WEST GERMANY

Prepared for the
House Committee on Science and Technology

Edith Fairman Cooper
Analyst in Social Sciences
Science Policy Research Division
May 24, 1982

(VII)

FOREWORD

The current and future conditions of the Nation's scientific and engineering manpower recently have become a major concern of many educators, industrial administrators, Members of Congress and others. There are several facets of this issue that have a bearing on the continuance of this country's lead in science and technological innovation and productivity. These include the quality and extent of pre-college science and mathematics instruction, which in large part determines the quality and number of scientifically and technically oriented high school students from which most future U.S. scientists and engineers must come; the current and potential shortage of high-quality college engineering faculty members; the deterioration and obsolescence of scientific and technical laboratory equipment in educational institutions; the current and potential shortage of manpower perceived in various disciplines of scientific and engineering fields; foreign national student enrollment and graduates in U.S. science and engineering schools; the unfavorable comparison made, in many cases, of U.S. scientific and technical capabilities with other major industrial countries; and the current and long-range impact of the supply and demand of scientific and technical manpower on the Nation's economy and security.

The terms "science" and "engineering," two distinct technical areas, at times become blurred in meaning, especially when used concurrently. Science has been defined as "the systematic knowledge of the physical world," and engineering as "the knowledge of how to apply science for the use of mankind." 1/ Although there are many "historical, cultural, and other differences between scientists and engineers, . . . engineering cannot exist without science and conversely, . . . science . . . must be mindful of the needs of engineering." 2/ This report recognizes the differences between the two fields, although the terms are used together in most cases.

This five-part report examines several aspects of science and engineering education as it relates to science and engineering (S/E) manpower. Part I discusses pre-college science and mathematics curricula that have a bearing on future career decisions of students and that will subsequently affect the supply of scientific and technical manpower; the importance of science and technology in higher education for the scientific as well as the nonscientific and technically oriented student; and how all of this relates to the basic technical literacy of the U.S. population. Also discussed are the current engineering faculty shortage and the state of college and university laboratory equipment. The status of the supply and demand of S/E manpower is reviewed through a discussion of the number of recent S/E degrees awarded to undergraduate and graduate students and the current demand in some of these degree areas; and the number of non-U.S. citizens enrolled in, and graduating from, the Nation's science and engineering schools. The question regarding whether or not a shortage in science and engineering manpower actually exists is examined, and a final chapter reviews the implications that the issue of science and engineering education

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1/ Young, Leo. Science and Engineering. Science, v. 209, Sept. 26, 1981. p. 1475.

2/ Ibid.

has on the Nation's scientific and technological role in the world, and some possible solutions to the problems involved, as recommended by some experts and various corporate and professional organizations.

Part II of the report examines the science and engineering education instruction provided in three other industrialized countries--Japan, the Soviet Union, and West Germany and how it relates to the technical competence of their general populace.

Part III presents forecasts concerning the possible future supply of and demand for S/E manpower in the United States, and trends of the future supply of scientists and engineers in the Soviet Union. [3]

Part IV examines the supply of engineers and scientists in the Department of Defense in both the military and civilian sectors.

Part V is a historical overview of congressional interest and actions regarding these issues, which includes some of the actions also taken by the National Science Foundation. The discussion begins with the Pre-Sputnik era, 1953 to 1957, and continues with the Post-Sputnik period, 1958 to 1970. A review of such actions from 1971 to 1982 is provided, along with those taken by Congress and the NSF up to April 1982.

A selected annotated bibliography and appendices also are included.

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[3] Similar trends for Japan and West Germany were unavailable.

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EXECUTIVE SUMMARY

PRE-COLLEGE SCIENCE AND MATHEMATICS CONCERNS

Science and mathematics instruction at the pre-college level has a significant relationship to the future supply of scientific and technical manpower in the Nation. How teachers at this educational level approach science instruction--what they know or do not know about science, their impressions regarding the importance of science instruction, and how they actually teach science--have a direct bearing on how their students perceive the importance of science and the interest they will probably have in the subject.

Because of the "back-to-basics" movement, in which science is not considered to be a "basic," science does not appear to receive as much emphasis as the "basic" courses on the pre-college level and relatively little time is spent on its instruction--an average of 19 minutes per day in kindergarten through the 3rd grades, and 35 minutes per day in grades 4 through 6.

Most elementary school teachers in the United States who were surveyed by the National Science Foundation (NSF) were found to lack confidence in their knowledge about science and their understanding of scientific concepts. Those teachers who did have confidence in certain aspects of their scientific knowledge reported that, in most instances, they did not have the time or material resources to develop what they would consider a meaningful scientific program.

On the junior high school level, NSF found that most science programs seemed more effective than those at the elementary school level. Most junior high schools surveyed had designated science teachers. What was actually taught in this subject, however, was left to the discretion of the teacher, similar to elementary school. The most commonly taught science courses were found to be general science, earth science, life science, and physical science.

On the high school level, biology, chemistry, and physics were the most commonly offered science courses. Biology seemed to be the most frequently required science course for graduation in schools across the Nation with such requirements. Essentially, it is the last science course taken by a large number of high school students.

Assessments of scientific achievement, made by the National Assessment of Educational Progress (NAEP) of the Education Commission of the States, discovered that there was a downward trend in science achievement of 9- and 13-year-olds, from the first to the second assessment. Results from a third assessment showed the trend to be improving for these age levels. The 17-year-olds tested showed a continued decline in scientific competence in all three measurements that were administered.

Mathematics, which is considered a "basic," seems to be well emphasized on the pre-college level and a concentration on computational skills from the 2nd grade through the 12th grade is evident. About 95 percent of all elementary teachers surveyed apparently felt "adequately qualified" and "very well qualified" to teach mathematics. About an average of 45 minutes per day was reported to be spent teaching mathematics in grades K-3, and 50 minutes in grades 4-6.

In junior high school, two years of mathematics above the elementary level was required by most schools surveyed by NSF. One year of algebra also was taken by most students.

At the high school level, the majority of students in schools surveyed were found to take as many mathematics courses as were necessary for pre-requisites for other courses, such as science courses required for a future college major or vocation. NSF found that 21 percent of the States require more than one year of mathematics for high school graduation, 57 percent require one year, and 22 percent require less than one year.

The NAEP assessments for mathematical achievement of 9-, 13-, and 17-year-olds showed that there was a decline in such achievement during the 1970s. There also has been a notable 32-point decline in the mathematical portion of the Scholastic Aptitude Test (SAT) scores, from 502 in 1963 to 470 in 1977, as well as in the verbal portion of the test.

The quality of pre-college mathematics and physical science instruction may be threatened because of a detected shortage in such teachers. The National Council of Teachers of Mathematics (NCTM) has revealed that, at the close of the 1977-78 school year, nearly 10 percent of mathematics teaching positions across the country were vacant. Such a shortage is reaching the crisis level according to the NCTM.

COLLEGE-LEVEL SCIENCE AND ENGINEERING CONCERNS

The technical literacy of the general population of the United States has become a recent concern because of the state of pre-college science and mathematics instruction. Also, the status of college and university level scientific instruction of non-science majors may have a bearing on the scientific competence of the populace. A National Research Council report has found that, at the undergraduate level, individuals who are not majoring in a scientific field may not be receiving an understanding of science and technology adequate for those who may become civil and professional leaders. Furthermore, the report notes, the educational needs of persons who are scientific majors, but who do not plan to seek scientific careers upon graduation, are not being sufficiently considered.

Recent trends in doctorate program enrollments in the mathematical, physical, and life sciences show declines that may later affect the numbers of qualified individuals available to fill vacant faculty positions that are predicted for the mid-1990s due to the probable retirement of tenured college and university faculty in these fields. A similar concern exists at the graduate level in college and university engineering departments where graduate-degree production in many engineering disciplines has declined.

Since the 1970s, the number of engineering doctoral degrees awarded has dropped 25 percent. This decrease is believed to be largely contributing to a developing engineering faculty shortage. Also significantly affecting this shortage is the luring away of engineering bachelor's degree recipients by various industrial companies offering comparatively large starting salaries. Many tenured professors in these fields also are said to be leaving the universities for higher paying industry jobs. Academic employment has become less attractive for these reasons, along with the fact that university laboratory equipment and facilities are deteriorating. The average age of most of this equipment reportedly exceeds 14 years. In addition, undergraduate engineering school enrollments have almost doubled since 1973, placing increased workloads on a smaller number of engineering faculty members and graduate assistants.

Some suggestions that have been made to help alleviate these problems have been to raise engineering faculty salaries; encourage the pooling of laboratory equipment funds and the sharing of apparatus between university departments, and establish regional instrumentation centers; encourage greater flexibility of Federal research grant and contract procedures; and encourage university-industry cooperation.

Some firms already have pledged support for improving the situation. These include the Exxon Corporation, du Pont, General Electric, General Motors, Amercian Telephone and Telegraph (AT&T), International Business Machines (IBM), Union Carbide, General Telephone and Electronics, and the U.S. Semiconductor Industry Association.

STATUS OF SCIENCE AND ENGINEERING MANPOWER

According to Dr. John Slaughter, the NSF Director, there is currently a manpower shortage in nearly every degree level and specialty of engineering and the computer sciences, as well as in certain physical and biological science fields. Shortages in the scientific areas, however, do not appear to be as critical as those in various engineering fields. Computer science, nevertheless, is one of the fields in which personnel is in great demand. Recently, there has been a significant increase in the number of bachelor's degrees awarded in this area. In 1979 and 1980, there were also increases in the number of advanced degrees awarded in the computer field. In spite of such increases, because of the extensive demand for computer science professionals, the current supply is inadequate to meet that demand. This situation does not show signs of improving because the "computer world" seems to be advancing at such a rapid pace.

In the engineering field, electrical, electronic, and mechanical engineers with two to five years of experience seem to be the most in demand. During 1982, it has been predicted that such experienced personnel plus new graduates also will be sought in most of these engineering fields, as well as in chemical engineering.

There has been a particularly noticeable increase in recent years in the number of foreign science and engineering graduate students in the United States. The increase has become most noticeable in the area of petroleum engineering. If this trend continues throughout the 1980s, NSF projects that nearly all petroleum engineering graduate students will be non-U.S. citizens. Also, NSF projects that non-U.S. citizens will comprise over 50 percent of graduate students enrolled in most science and engineering fields. As a result of the decline in U.S.-born engineering students, faculty, and graduates, non-U.S. citizens are filling vacancies in college and university classrooms, unfilled faculty positions in academia, and vacancies in technical-industrial occupations.

An across-the-board engineering shortage is questionable, according to leaders of the Institute of Electrical and Electronics Engineers, Inc. Basically, they believe that there is a balance in supply and demand of U.S. engineers, although there may be shortages in certain specialties.

The United States is still considered to be the world leader in most scientific and engineering disciplines. If solutions are not found, however, for most of the problems the Nation faces in its science, mathematics, and engineering education and manpower, this lead may be jeopardized.

The current and future condition of the country's scientific and engineering manpower may affect significantly the Nation's scientific and technological capabilities to produce new and effectual innovations and to be economically competitive with other major nations (such as Japan, West Germany, and the Soviet Union). It also may have a direct impact on national security and military preparedness. The Soviet Union in particular, according to an expert in Soviet mathematics and science education, has made a tremendous investment in manpower, the general population has made important educational achievements, and the country has acquired a superb science and technology manpower pool that will affect its technical, industrial, and military power. In comparison, such a statement probably cannot be made about the United States.

SCIENCE AND ENGINEERING EDUCATION IN JAPAN, THE SOVIET UNION, AND WEST GERMANY

In comparison with the United States, Japan, the Soviet Union, and West Germany seem to place more emphasis on science and mathematics instruction at all educational levels.

A major joint NSF and Department of Education study discovered that managerial positions in both the Government and industries of the Soviet Union and especially Japan, were staffed by individuals with engineering degrees. Furthermore, especially in Japan and the Soviet Union, all students are exposed to a science and mathematics program from the first grade through the completion of the upper secondary level.

Japanese students are required to spend a minimum of 210 days per year in school. Most schools, however, are open between 240 and 250 days per year, compared with about 180 days in the United States. In the Soviet Union, students spend 240 days per year in school. In West Germany, students typically spend 185 days per year in school.

In the Soviet Union, 98 percent of all students complete secondary school and, consequently, receive comprehensive instruction in arithmetic, algebra, geometry, and calculus, along with physics, chemistry, astronomy, biology, geography, and other such courses. In the United States, more than 56 percent of the State and local school systems do not require any particular mathematics courses, or require only one such course for high school graduation.

Data for 1979 indicate that the United States surpassed the Soviet Union in the total number of graduates for all fields. The Soviet Union, however, graduated more than twice as many science and engineering students as did the United States, and almost five times as many engineers. Comparisons of 1980 engineering graduates in the United States, Japan, and the Soviet Union, showed that the Soviet Union had the largest total number of engineering graduates and the largest percentage of engineering graduates relative to total population, while Japan ranked second, the United States third, and West Germany fourth in both categories.

In contrast to a prediction that the general population of the United States is heading toward scientific and technological illiteracy, the general populations of Japan, the Soviet Union, and West Germany appear to have a strong level of understanding of science and mathematics.

POTENTIAL DIRECTIONS FOR SCIENCE AND ENGINEERING MANPOWER

Through predictions developed by the Bureau of Labor Statistics (BLS), the employment demand for scientists and engineers in science and engineering occupations, at all degree-levels, has been projected to increase by 40 percent between 1978 and 1990. In view of this growth, the BLS has predicted that about 180,000 new jobs will be available in the mathematical, physical, life, and social sciences. In addition, they estimate about 480,000 new jobs will be created in the computer professions, and 250,000 in engineering. The BLS also forecasts that the most rapid growth in occupational demand will be in the computer professions.

In 1990, the BLS has stated that a total of about 1.4 million scientists and engineers will be required to fill new jobs that will be created between 1978 and 1990, and to replace experienced workers who will retire or die during that 12-year period.

The National Center for Education Statistics (NCES) has predicted that, by 1985, the total number of engineering degrees conferred will increase to about 73,400, before dropping to about 65,100 in 1990. Significant decreases in the number of bachelor's degrees awarded in all fields by 1990 have been forecast by the NCES, except in environmental, mining, and nuclear engineering where the trends show no change in the number of degree recipients. The NCES data projects that bachelors's degrees in computer science, however, probably will increase by 58 percent between 1979 and 1987. Any such increase, warns the Scientific Manpower Commission (SMC), will intensify an already evident faculty shortage, at least for a short term. Doctoral degrees in computer science, the SMC has stated, average less than 200 per year.

Lt. Col. Jim Graham, of the U.S. Air Force has predicted that, overall, engineering manpower trends show that, between 1981 and 1990, there will be 731,000 jobs available for 617,000 engineering graduates, indicating a 114,000 personnel shortage in all engineering disciplines.

In the Soviet Union, the only country other than the United States for which future projections of science and engineering manpower were found, the total Candidate of Science degrees awarded in science and engineering in 1979, 20,800, have been predicted to drop to about 19,700 in 1985, and remain stationary in 1990. Such degrees conferred in the physical, life, and mathematical sciences are projected to decline to 7,400 in both 1985 and remain at that level in 1990. Total Candidate of Science degrees awarded in engineering specifically in 1979 were 11,500. Such degrees are anticipated to decrease to 10,800 in 1985, but slightly increase to 10,900 in 1990.

THE SUPPLY OF U.S. DEPARTMENT OF DEFENSE SCIENTISTS AND ENGINEERS

The supply and demand of scientists and engineers also play a role in the area of national defense. Between 25 and 35 percent of the total number of employed scientists and engineers in the Nation are supported by defense work. An expert has cautioned that the increasing gap between the scientific training of U.S. citizens and their Soviet counterparts places a serious threat to both the U.S. economic and military security.

The effects of the perceived shortage of scientists and engineers on the Department of Defense (DOD) have been reported as producing a decline in military preparedness, an increase in the cost of weapons design, a drop in productivity, and reduced innovativeness. As a result of these and other concerns, the supply of scientists and engineers in the DOD is discussed in this report.

Industry has been outbidding, for example, the U.S. Air Force for technically qualified personnel, because of higher starting salaries (about $7,000 more). The military, as well as academia and other branches of the Federal Government, appear to be unsuccessful in competing with higher industry salaries. As a result, by October 1981, Air Force recruitment of engineering graduates had dropped to about one-and-one-half percent, from five percent in 1968. At the time of this writing, the Air Force is nearly 1,100 Military Engineering Officers short of its minimum requirement. The Air Force Systems Command (AFSC), the primary user of engineers in the Air Force, is experiencing a 10 percent shortage of military engineers (over 500 vacancies). Since 1978, as a result of the engineering shortage, the AFSC has encountered a net loss of nearly 7,500 man-years of engineering experience.

Also experiencing shortages is the Army's Electronic Research and Development Command. In its seven laboratories, at least 120 vacancies have been reported in science and engineering positions.

A HISTORY OF CONGRESSIONAL CONCERN AND SOME ACTIONS TAKEN BY THE NATIONAL SCIENCE FOUNDATION RELATED TO SCIENCE AND ENGINEERING EDUCATION

Science and engineering education has been a concern in the United States since the early 1950s. Several programs were established, mainly through the

National Science Foundation 4/ to help ameliorate the problem. Certain current problem areas seem to parallel some of the concerns about science and engineering education that were notable 20 to 30 years ago. Those factors that appear to be most prominent are the following:

--Shortages in science and engineering manpower were reported in the second annual NSF report to President Truman. One of the reasons given for the shortages was that industry was offering jobs with high starting salaries to science and engineering bachelor's degree recipients. A January 17, 1953 article in the New York Times stated that NSF concluded that promising students probably would not turn down high-salaried industry-jobs in favor of four more years of postgraduate work;

--High school science teachers were reported to be lured away by industry's large starting salaries as early as 1955;

--The Soviet Union graduated more than three times as many engineers than the United States in 1955--50,000 to 15,000 respectively;

--In the early 1960s, a book on science and engineering education in the Soviet Union reported that the Soviets emphasized science and engineering education and were outproducing the United States in the number of engineering graduates;

--In the mid-1960s, an American Council on Education report, entitled Man, Education, and Work, concluded that ". . . the American education system is almost totally geared to the aims and interests of the college-preparatory students and thus neglects the great majority of youths." The report suggested

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4/ Other Federal Government agencies that have not been discussed in this report, but which also have science and engineering education programs are: the National Aeronautics and Space Administration, Department of Commerce, Department of Energy, Department of Health and Human Services, Department of Defense, Environmental Protection Agency, Department of the Interior, the Department of Agriculture, the Smithsonian, and the Department of Education.

that "higher education [should] take immediate steps to assure an adequate supply of technical and highly skilled manpower below the bachelor's level;" 5/ and, about 15 years ago,

--An international study evaluating the mathematical achievements of students in 12 nations found that students in U.S. schools ranked low in mathematical attainment compared with pupils in five other nations--Japan, England, Sweden, France, and Belgium.

In essence, the problems that the Nation currently faces concerning science and engineering education and, consequently, its supply of scientists and engineers, do not appear to be new.

Before the Soviet's earth satellite, Sputnik I, was launched in October 1957, there was significant congressional concern about the state of U.S. science education. Several forms of legislation were introduced between the 84th Congress and the end of the first session the 85th Congress, immediately prior to the launching of the first Sputnik. No definitive action occurred. Following Sputnik I, public demand was aroused for more adequate science education instruction. Congress reacted with the passage of the National Defense Education Act in September 1958, which enacted a four-year, $887 million program for student loans, fellowships, and other aids to improve U.S. scientific manpower resources.

Today, the Soviet Union is no longer the only country that has surpassed the United States in the number of engineering degrees awarded each year.

5/ Venn, Grant. Man, Education, and Work. Washington, American Council on Education, 1964. 184 p. Pages 139-140 of the report are referred to in the quoted material from a newspaper account that appeared in the Apr. 31, 1964 edition of the New York Times, p. 1. (See Selected Annotated Bibliography, Part V, p. 217.)

Japan, according to the data available, conferred more engineering degrees in absolute numbers than did the United States in 1980, by about 9.8 percent. West Germany also has been found to place more emphasis on science and mathematics instruction than does the United States.

Within the last few decades, Japan has been reported to have "gained world leadership in the production of steel, the manufacture of automobiles, and the development of many electronic devices." 6/ The Soviet Union's "educational mobilization" also has been called a "formidable challenge to the national security of the United States, [and] one that will be more difficult to meet." 7/

Between 1959 and 1962, the President's Scientific Advisory Committee released three reports concerning the strengthening of science and engineering education--(1) Education for the Age of Science (May 24, 1959); (2) Scientific Progress, the Universities, and the Federal Government (November 15, 1960); and (3) Meeting Manpower Needs in Science and Technology (December 12, 1962). All three reports emphasized the need for an expansion of the role of the Federal Government in enhancing science and engineering education and for improving the quantity as well as quality of scientific and engineering manpower. Some of the recommendations made in these reports--scientific curricula improvement, support to develop scientifically and technically talented individuals, support of fellowships for doctoral candidates, a national goal to increase annual engineering, mathematics, and physical science Ph.D.-degree awards to

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6/ Willenbrock, F. Karl, and Cecil H. Green. United States and Technological Preeminence, p. 1319.

7/ Glockner, David. Wirszup: U.S. Science Education Lagging. The Chicago Maroon. Apr. 7, 1981. p. 1.

7500 by 1970--were accomplished mainly through the efforts of the NSF. [8] Several problems identified at the time of the writing of these reports continue to exist today--including pre-college science and mathematics teacher shortages, inadequate understanding of science and technology by the general U.S. population, and fewer engineering graduates seeking academic employment. An increased role for the Federal Government in helping to resolve these problems may be necessary for the 1980s and for future decades.

Federal funding for science and engineering education programs in fiscal year 1982 was $20.9 million, the lowest in almost 25 years. For fiscal year 1983, the Administration has eliminated all funding for NSF programs in these areas. Instead, it has supported graduate research fellowships in sciences and engineering ($15 million has been requested). Recognizing that there are problems in science education and disagreements on how to solve them, the NSF, according to its Director, John Slaughter, will "play a catalytic role," to help define precise needs, and support the efforts of state and local governments, scientific and professional organizations, private industry, and other Federal Government agencies to solve them.

Legislation has been introduced in the 97th Congress (H.R. 5254, Reps. Fuqua and Walgren, the National Engineering and Science Manpower Act of 1982; H.R. 5742, Rep. Skelton, to create a National Commission on Science, Engineering, and Technology Education; and S. 2421, Sen. Glenn, the National Engineering and Science Manpower and Education Act of 1982) recommending various actions that can be taken by the Federal Government. Even those calling for increased Federal involvement, however, argue that such responsibility does not seem to be that of the Federal Government alone. New initiatives involving cooperation between industry, academia, State and local governments, and the Federal Government often have been mentioned as providing a productive approach to evolving workable solutions for all aspects of current concerns with the state of the Nation's scientific and engineering education and manpower.

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[8] See appendix 14 for evaluations of some NSF science education programs.

Some attempts at such cooperation already are underway. On January 17-19, 1982, there was a Forum on Engineering Manpower, held in San Antonio, Texas, sponsored by "five leading engineering societies and attended by some 80 leaders of industry, education and government". Arizona State University is "developing a $32 million 'Center for Excellence in Engineering' that represents a partnership of the state government, the university and private industry." A National Engineering Action Conference convened on April 7, 1982 in New York City with representatives of industry, academia, professional societies, and the Government to discuss solutions to the problem.

PART I: SCIENTIFIC AND TECHNICAL EDUCATION IN THE UNITED STATES AS IT RELATES TO SUPPLY AND DEMAND OF SCIENCE AND ENGINEERING MANPOWER

I. INTRODUCTION AND SUMMARY

The state of pre-college-level and college-level science and mathematics instruction and emphasis for scientifically, as well as non-scientifically, oriented individuals has a direct influence on the supply of U.S. technical manpower. 9/ Recent studies have discovered that, as a result of the "back to basics" movement, science, which is not considered to be a "basic," does not receive much emphasis at the pre-college level and relatively very little time is spent on its instruction. In addition, mathematics instruction emphasizes "computational skills, not problem solving." 10/

There is a shortage of pre-college mathematics and physical science teachers that may be affecting the quality of instruction in these areas. "It is widely known," a report has stated, "that when positions cannot be filled through new hiring of qualified instructors, they are often filled by teachers with lower subject matter qualifications or by the transfer of tenured teachers from other subject areas. Thus, inevitably, many secondary school mathematics and physical science teachers have insufficient training to teach courses in these subjects." 11/ Furthermore, a large number of

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9/ Galambos, Eva C. Engineering and High Technology Manpower Shortages: The Connection with Mathematics. Atlanta, Georgia, Southern Regional Educational Board. 1980. p. 3.

10/ Walsh, Efthalia, and John. Crisis in the Science Classroom. Science 80. v. 1, no. 6, Sept./Oct. 1980. p. 17.

11/ National Science Foundation and Department of Education. Science and Engineering Education for the 1980's and Beyond. Washington, U.S. Govt. Print. Off., Oct. 1980. p. 49.

pre-college science and mathematics teachers expressed feelings of inadequacy in teaching these subject areas. 12/

A National Research Council study has found that at the undergraduate university and college level, persons who have non-scientific majors--in law, theology, journalism, elementary education, and other areas,--and who may eventually become civil and professional leaders, are not receiving "the understanding of science and technology that they need to function effectively." 13/

As a result of the factors mentioned in the Foreword of this report, it has been announced that "there is a growing [technical] illiteracy" in the general U.S. population which, if not reversed, "means that important national decisions involving science and technology will be made increasingly on the basis of ignorance and misunderstanding." 14/

A large number of tenured college and university faculty members are due to retire by the mid-1990s. Recently, there has been a noticeable decline in Ph.D. program enrollments in the mathematical, physical, and life sciences. This situation, if not reversed, may result in an insufficient number of qualified teachers to fill future faculty vacancies. In college and university engineering departments, there is a similar concern at the graduate level where graduate-degree production in many engineering disciplines has decreased, thus contributing to a developing engineering faculty shortage. Apparently there is a diminishing attractiveness to academic employment in some areas due, in

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12/ Ibid.

13/ National Research Council. Commission on Human Resources. Science for Non-Specialists: The College Years. Committee for a Study of the Federal Role in the College Science Education for Non-Specialists. Report to the National Science Foundation. Washington, National Academy Press. 1981. p. xi.

14/ Technical Illiteracy Threatens U.S. Science. Science News, v. 118, Nov. 1, 1980. p. 276.

part, to relatively large starting salaries being offered by industry to bachelor's degree-level recipients, which deters some students from seeking advanced degrees and teaching positions; increased undergraduate engineering school enrollments (which means heavier teaching loads per instructor); and the obsolescence of laboratory equipment needed for teaching and research.

An employment shortfall of scientific and engineering degreed personnel seems to be developing specifically at the graduate level in computer science, geological and geophysical engineering, petroleum engineering, and others, while the demand for such graduates appears to be increasing. This belief, however, is not a universal one. There is no consensus on the science and engineering shortage issue. Leaders of the Institute of Electrical and Electronics Engineers, Inc., for example, have stated that there is a balance in supply and demand of U.S. engineers, although there may be shortages in some areas or specialties.

Non-U.S. citizens are filling the places of U.S.-born students in both college and university classrooms and subsequently in faculty positions in academia and in technical-industrial occupations. In 1980, 46.3 percent of all engineering doctoral degrees were awarded to foreign national students.

Several experts that testified at the October 1981 House hearings of the Committee on Science and Technology agreed that there are important concerns that need to be addressed regarding scientific and technical education and its impact on U.S. scientific strength, technological innovation, productivity, the economy, national defense, and the maintenance of the Nation's technological lead vis-a-vis other Nations.

II. PRE-COLLEGE SCIENCE AND MATHEMATICS CONCERNS

A. ELEMENTARY SCHOOL

1. Science Instruction

For pre-college-level students, the importance of science to them and their interest in science 15/ depends on what their teacher(s) believe about the importance of science education, knows or does not know about science, and does or does not do about teaching science, according to the findings of a National Science Foundation (NSF) report. 16/ In elementary school, one teacher is usually responsible for the instruction of all academic subjects. A teacher's perception regarding his or her ability to teach various subject areas was found to correspond with the amount of time spent per day on each subject. Of all the elementary teachers responding to an NSF survey (1,667 out of 4,829 total respondents) 17/ 63 percent (nearly two-thirds) felt

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15/ The NSF defines "science" to include the natural sciences, social sciences, and mathematics. Science (the natural and social sciences) and mathematics will be treated separately in this report.

16/ Stake, Robert, and Jack Easley, Jr. Case Studies in Science Education. Executive Summary. Center for Instructional Research and Curriculum Evaluation and Committee on Culture and Cognition. University of Illinois-Urbana-Champaign. Jan. 1978. In National Science Foundation. Directorate for Science Education. The Status of Pre-College Science, Mathematics, and Social Studies Educational Practices in U.S. Schools: An Overview and Summaries of Three Studies. Washington, U.S. Govt. Print. Off., July 1981. p. 19:1.

17/ In 1977, a national survey was conducted for the NSF by the Research Triangle Institute to assess the "needs and practices in pre-college science, mathematics, and social studies in the nation's schools." Weiss, Iris R.
(continued)

"very well qualified" to teach reading. In contrast, only about 22 percent of the teachers felt "very well qualified" to teach science. Correspondingly, from kindergarten to the 3rd grade level (K-3), teachers spent an average of 95 minutes per day teaching reading. From grades four through six (4-6) reading was taught on an average of 65 minutes per day. In grades K-3, however, teachers spent an average of 20 minutes per day teaching science and, in grades 4-6, 30 minutes per day. About 60 percent of the teachers, however, felt "adequately qualified" to teach science.

For mathematics instruction, 49 percent of the teachers felt "very well qualified" to teach this subject and spent, on the average, 45 minutes per day in grades K-3 and 50 minutes per day in grades 4-6. 18/ (See chart 1 on the following page.)

Dr. Iris Weiss, who conducted this particular NSF survey, found that, of the States and districts responding, only about 25 percent of the States and 40 percent of the districts set requirements for the minimum amount of time for elementary grade teachers to spend on science, mathematics, and social studies instruction. The recommended time was an average of 20 minutes per day for science and social studies and 30 minutes per day for mathematics in grades one through three. Few districts set guidelines for kindergarten. Those that did required about 15 minutes per day for each of these subject

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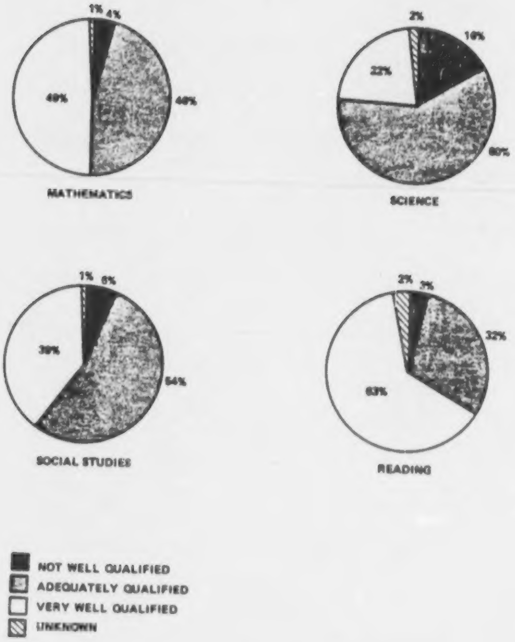
(continued) 1977 National Survey of Science, Mathematics, and Social Studies: Education Highlights Report. Center for Educational Research and Evaluation. Research Triangle Institute, Research Triangle Park, N.C., Mar. 1978. In National Science Foundation. Directorate for Education. The Status of Pre-College Science, Mathematics, and Social Studies Educational Practices in U.S. Schools: An Overview and Summary of Three Studies. p. 12-14.

18/ Ibid.

CHART 1



ELEMENTARY TEACHERS' PERCEPTIONS OF THEIR QUALIFICATIONS TO TEACH MATHEMATICS, SCIENCE, SOCIAL STUDIES, AND READING

Source: Weiss, Iris R. 1977 National Survey of Science, Mathematics and Social Studies: Education Highlights Report. Research Triangle Park, N.C., Research Triangle Institute, Mar. 1978. p. 13.

areas. In grades 4-6, 30 to 40 minutes per day were recommended for the minimum amount of time to be spent on each subject individually. 19/

Dr. Weiss concluded that one out of six elementary school teachers responding to the NSF questionnaire felt inadequately prepared to teach science. In addition, for many of the teachers who felt this way, there were no district science supervisors or school science department heads to assist them. Ninety percent of elementary school principals felt well qualified to supervise instruction in reading, mathematics, and social science. In science supervision, however, nearly 20 percent who responded felt less competent. 20/

Two university researchers, Robert Stake and Jack Easley, found the following situation regarding the teaching of pre-college-level science from case studies that they compiled. 21/

> Most schools we studied had some written policy about what and how elementary science should be taught . . . but what actually was taught was left largely to individual teachers. By and large, the elementary teachers did not feel confident about their knowledge of science, especially about their understanding of science concepts. Even those few who did like science and felt confident in their understanding of at least certain aspects of it often felt that they did not have the time nor material resources to develop what they thought would be a meaningful program. As a consequence, science had been deemphasized at the elementary school level, with some teachers ignoring it completely. 22/

19/ Ibid., p. 22.

20/ Ibid., p. 12.

21/ Stake, Robert E., and Jack A. Easley, Jr. co-directed a team of educational researchers at the University of Illinois to conduct an NSF study to observe the teaching and learning of science education (including mathematics and social studies) in the Nation's schools. Surveys were taken and case studies prepared indicating their findings.

22/ Stake, Robert E., and Jack A. Easley, Jr. Case Studies in Science Education: Design, Overview and General Findings, v. II. Center for Instructional Research and Curriculum Evaluation and Committee on Culture and Cognition, University of Illinois at Urbana-Champaign. Washington, U.S. Govt. Print. Off., Jan. 1978. p. 13:5.

Only a few elementary teachers were found who had strong interests and understanding of science. The number of such teachers was so small, Stake and Easley stated, that it could not be concluded that "even half of the Nation's youngsters would have a single elementary school year which their teacher would give science a substantial share of the curriculum and do a good job of teaching it." 23/

This NSF survey determined that there is a heavy reliance on textbook material for elementary science instruction. In most elementary schools canvassed, learning science by reading from a textbook permeated the science program. 24/ Laboratory activities were stressed by only about 30 to 40 percent of the teachers surveyed. Science is basically taught by reading and lecturing. 25/

Elementary science teachers are very uncomfortable with science, a junior high school principal has commented. According to him, science instruction probably should be given to children in upper grades, because about all that can be expected from the elementary level is a "solid preparation in reading,

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23/ Ibid., p. 19:3.

24/ Ibid., p. 13:6.

25/ Helgeson, Stanley L., Particia E. Blosser, and Robert W. Howe. The Status of Pre-College Science, Mathematics, and Social Science Education, 1955-1975. v. I, Science Education. Ohio State University, Center for Science and Mathematics Education. Prepared for the National Science Foundation. Directorate for Science Education. Office of Program Integration. Washington, U.S. Govt. Print. Off., 1978. p. 32.

especially comprehension, 26/ and mathematics when they reach . . . junior high school." 27/

2. Mathematics Instruction

It has been reported that "back to basics" thinking has influenced significant changes in the elementary and secondary school level curricula of the Nation. The most commonly understood definition of "back to basics," according to Stake and Easley, is an increased emphasis on reading and arithmetic. This, as discussed in a recent report, 28/ has "damaged science and math teaching" in elementary school. Since science is not considered to be a "basic," very little time is spent on its instruction. While mathematics is considered to be a "basic," the new approach to teaching mathematics has been viewed as "extremely narrow" because it centers on "computational skills, [and] not on problem solving." This "almost exclusive concentration on computation [continues] from second grade math to that in senior year." 29/

Ninety-five percent of all elementary teachers responding to the NSF survey by Weiss reported that they felt "adequately qualified" (46 percent) or "very well qualified" (49 percent) to teach mathematics. 30/ The

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26/ One school district surveyed by Stake and Easley reported that elementary science instruction there was in trouble because the old science books were replaced for the entire science program. The new science books seemed to be difficult for students to understand. The teacher had to read the lesson to the children or explain to them what they had read.

27/ Stake, Robert, and Jack Easley, Jr. Case Studies in Science Education: Design, Overview and General Findings. p. 13:6.

28/ Walsh, Efthalia and John. Crisis in the Science Classroom, p. 22.

29/ Stake, Robert, and Jack Easley, Jr. Case Studies in Science Education: Executive Summary, p. 19:3.

30/ Weiss, Iris R. 1977 National Survey of Science, Mathematics and Social Studies: Education Highlights Report, p. 13.

textbook is a dominant source for mathematics instruction, along with a daily lecture and discussion period. As previously stated, about 45 minutes per day was reported to be spent on teaching mathematics in grades K-3, and 50 minutes in grades 4-6. The time spent, however, may vary from teacher to teacher and much less time than indicated may actually be used. 31/

B. SECONDARY SCHOOL

1. Science Instruction

At the junior high school level (grades 7-9), Stake and Easley found that science programs seemed to "operate somewhat more effectively than the elementary science programs." Most junior high schools were found to be departmentalized with designated science teachers. What was actually taught in the classroom, however, was left to the discretion of the teacher, similar to the situation at the elementary school level. "The philosophical orientation of the teacher played a key role in determining what content was taught and how it was taught." 32/

Generally, the most common science courses found to be taught in grades 7-9 were general science, earth science, life science, and physical science. 33/ Most of the courses lasted one year.

31/ Suydam, Marilyn N., and Alan Osborne. The Status of Pre-College Science, Mathematics, and Social Science Education: 1955-1975. V. II, Mathematics Education. Ohio State University, Center for Science and Mathematics Education. Prepared for the National Science Foundation, Directorate for Science Education, Office of Program Integration. Washington, U.S. Govt. Print. Off., 1977. p. 52.

32/ Stake, Robert E., and Jack Easley, Jr. Case Studies in Science Education: Design, Overview and General Findings, p. 13:6-7.

33/ National Research Council. The State of School Science: A Review of the Teaching of Mathematics, Science and Social Studies in American Schools, and Recommendations for Improvements. Commission on Human Resources. Panel on School Science. Washington, June 1979. p. 16.

At the high school level (usually grades 10-12, but some high schools were found that also included grade 9), the most generally offered science courses were found to be biology, chemistry, and physics. In the schools that had grades 10-12 only, more diverse courses usually were offered--physiology, Chemistry II, Physics II, and so on. 34/

An elitist feeling among some teachers in high school science departments was found by the NSF, especially among physics and chemistry teachers. Such teachers appeared to feel that they were there to teach only the exceptional students. One teacher was noted as saying:

> . . . Of course I'm elitist--I'm here to teach the elite of this school. If they disappear so do I and the physics class. You want to know why physics classes have gotten smaller in the past few years? It's because parents have become anti-science and they don't want their kids to be part of the science elite. 35/

Some parents interviewed seemed to express similar feelings. A parent of a college-bound student stated:

> I've been very disappointed with the district for watering down the [science] courses. There used to be a really strong physics program. . . but then [the teacher] decided he needed to accommodate the low to middle achiever so he threw out the good program and came up with this other one that is less comprehensive. It really hurt the well-motivated kids. 36/

In contrast, a parent of a student unlikely to attend college commented:

> I think it would be all right if students didn't take any science at all at the high school level . . . . There are a lot of things kids are never going to use again. 37/

34/ Weiss, Iris R. Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education. Prepared for the National Science Foundation. Research Triangle Park, N. C., Center for Educational Research and Evaluation. Mar. 1978. p. 56.

35/ Stake, Robert E., and Jack Easley, Jr. Case Studies in Science Education: Design, Overview and General Findings, p. 12:19.

36/ Ibid.

37/ Ibid., p. 12:20.

Such elitist attitudes about science, Stake and Easley reported, may be one of the reasons that enrollments in chemistry and physics classes have declined in recent years.

Another reason that enrollments in some science courses have decreased may be that those courses have become electives. For example, enrollments in chemistry and physics, which usually were found to be electives (biology was basically a required subject), seemed to be decreasing more rapidly than the general enrollments in science courses. Explanations for the decline were given as--"more competition from other elective courses; the image of science and scientists is bad; reduced graduation requirements; opportunity to pick these subjects up in junior college, if needed; and the perception of high school students that the content of physics and chemistry are just not relevant." 38/ On the other hand, it was pointed out that "undoubtedly the individual teacher plays an important role in attracting students to his or her courses. In an instance where physics enrollment showed a slight increase after several years of decline, the physics teacher was settling into her third year and was highly respected by students." 39/

Several high school science teachers, high school counselors, and high school seniors were asked about what they felt was wrong with high school science courses, in the NSF survey. Out of those individuals responding, 40/ Stake and Easley found that:

> The teachers . . . were inclined to mark three or four weaknesses whereas the counselors and students one or two. The teacher pointed to things

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38/ Ibid., p. 13:4.

39/ Ibid.

40/ Out of 150 teachers surveyed, 101 responded; out of 86 counselors, 46 responded; all 375 seniors surveyed, responded.

that impeded their teaching, particularly remedial instruction in mathematics and the shortage of time and size of the class. The counselors were particularly impressed with inadequate lab facilities and field arrangements, and students and teachers took note of that too. The shortcoming most noted by senior students was the little attention given to individual students. 41/

Senior students 42/ also were questioned regarding what they considered to be "the one thing most wrong" with the science courses they had taken, and "the one thing most right." For the "most wrong," the largest percentage of students stated that the "courses were boring" (29 percent) and "overemphasized facts and memorization" (24 percent). For the "most right," 22 percent stated that the courses "stressed the basic facts," and 20 percent stated that the "courses were interesting." These responses seemed to indicate to the canvassers that "students were sensitive to and divided on the issue of stressing the 'basic facts' in high school science. Some liked it, some did not. Charges that the courses were undesirable elitist or impractical did not get much support from these students." 43/

a. Science Requirements for High School Graduation

The NSF (Weiss) survey questioned several State and district supervisors throughout the Nation by region--Northeast, South, North Central, and West--regarding science course requirements for high school graduation, 44/ if any,

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41/ Ibid., p. 13:5.

42/ Out of 375 senior students, 336 responded to the question regarding the "one thing most wrong" with science courses; 342 responded to the "thing most right" question.

43/ Stake, Robert E., and Jack Easley, Jr. Case Studies in Science Education: Design, Overview and General Findings, p. 13:5.

44/ Mathematics and social studies course requirements also were included.

in grades 9-12. The requirements also were broken down by the size of the State. 45/ It was found that, nationwide, 21 percent of the States require more than one year of science instruction; 53 percent, one year; 12 percent, less than one year; and 15 percent did not respond to this question which may indicate that they "have no requirements [for] the subject." It also was found that biology was the "most common" subject required in science for high school graduation. 46/

In an NSF report analyzing relevant literature related to pre-college science instruction, it was discovered that, for the majority of high school students, "biology is the last science course [taken], usually in grade 10." 47/ In fact, the percentage of students in grades 10-12 enrolled in biology increased from 1955 through the early 1970s, indicating that, among other reasons, "most students had to take a science course to meet graduation requirements and it appears they frequently selected biology." 48/

b. National Assessment of Science Achievement and Attitudes Toward Science

The National Assessment of Educational Progress (NAEP) report of the Education Commission of the States measured the science achievement of the

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45/ See appendix 1 for relevant table.

46/ Weiss, Iris R. Reports of the 1977 National Survey of Science, Mathematics, and Social Studies Education, p. 23-24.

47/ Helgeson, Stanley L., et al. The Status of Pre-College Science, Mathematics, and Social Science Education: 1955-1975. V. I, Science Education. p. 26.

48/ Ibid.

Nation's 9-, 13-, and 17-year-old students, during three different school years--1969-70, 1972-73, and 1976-77. The following results were found: 49/

> -[A] downward trend in science achievement [was] observed from the first to the second assessment [that] appear[ed] to be lessening for 9- and 13-year-olds in the third assessment. For these two age populations, it appears that a continued decline in achievement in physical science is accompanied by some stability in achievement in biology;
>
> -The achievement level of 17-year-olds continue[d] to decline. Seventeen-year-olds declined in performance from the first to the second assessment and from the second to the third assessment;
>
> -Students in extreme-rural communities, at each age level, . . . improved in science achievement during the eight years spanned by the three assessments of science; and
>
> -The position of most reporting groups relative to the national level of achievement showed little change over the three science assessments. [In addition,]
>
> > --A gap continued to exist in the achievement levels of whites and blacks: the achievement level of whites was higher than that of blacks in each assessment. However, black 13-year-olds improved in achievement on physical science exercises from the second to the third assessment; also
> >
> > --The achievement level of males at each age was higher than that of females in all three assessments of science.

Similarly to the 1976-77 achievement measurement, attitudes toward science also were assessed. 50/ Some of the findings showed that,

> -Attitudes of 13- and 17-year-olds toward science were in many cases very much alike. Similar percentages at these ages expressed favorable attitudes toward science classes, were interested in pursuing

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49/ National Assessment of Educational Progress. Three National Assessments of Science: Changes in Achievement, 1969-77. Selected Results from the Third National Assessment of Science. Prepared with the National Center for Education Statistics, U.S. Department of Health, Education, and Welfare, Education Division. Denver, Colorado, Education Commission of the States, June 1978. p. xiii.

50/ National Assessment of Educational Progress. Attitudes Toward Science: A Summary of Results from the 1976-77 National Assessment of Science. Denver, Colorado, Education Commission of the States, Oct. 1979. p. xiii.

science-related careers, used the scientific method of inquiry and were personally involved in solving science-related societal problems. . . .;

- More 9-year-olds expressed favorable attitudes toward science classes than 13- or 17-year-olds. They also appeared more willing than the older groups to try to help solve societal problems;
- About half the 13- and 17-year-olds, on the average, expressed favorable attitudes toward science classes and science-related careers;
- Males were more likely than females to have favorable attitudes toward science classes and science-related careers, to have had science-related experiences and to use the scientific method of inquiry. For teenagers, male and female support for research and awareness of the methods and philosophy of science were about the same; and
- At age 17, the following groups reported more favorable attitudes toward science classes and science-related careers than the nation as a whole: blacks, people living in the Southeast, people living in disadvantaged-urban communities and those living in big cities. Thirteen-year-olds in these groups exhibited more favorable attitudes toward science-related careers than the entire nation, while 13-year-olds living in advantaged-urban areas showed less favorable attitudes than the nation toward science classes and science-related careers.

2. Mathematics Instruction

Secondary school mathematics was found to be "just as traditional and work-oriented as learning to compute in the elementary school." 51/ At the junior high school level, two years of mathematics beyond elementary school was found to be generally required. One year of algebra was taken by most students and an emphasis was placed upon preparing as many students as possible for high school "academic track math courses." 52/

51/ Stake, Robert E., and Jack Easley, Jr. Case Studies in Science Education: Design, Overview and General Findings, p. 13:23.

52/ Ibid., p. 13:21. Usually students bound for college take special science and mathematics courses. Three "tracks" of mathematics are usually taken, the most difficult track consisting of "geometry, algebra II and trig, math analysis and advanced placement calculus." (Ibid., p. 12:17)

At the high school level, NSF surveyors found that most teachers and students seemed to accept mathematics as a " dry mechanical thing, to be done stoically." Students took as many mathematics courses as needed for pre-requisites for other courses, such as science courses required for a future college major or vocation. It also appeared "obvious and acceptable" that the reason for schools offering the "traditional high school mathematics content (algebra, geometry, trigonometry, and their continuation into analytic geometry and calculus)" was to prepare students for engineering, physics, economics, statistics, and other basic relevant uses of mathematics. "In this sense," surveyors found that "mathematics was a pre-vocational subject for many promising students. That mathematics experience [could] be of value for other purposes seemed less important." 53/

Senior students were asked, through a survey, what was "the thing most wrong" and the "most right" about mathematics courses. Out of 318 responding to the "most wrong" category, 31 percent checked that the courses were boring and 26 percent stated that the courses "were too much aimed at the 'bright kids.'" For the "most right" list, 40 percent indicated that the courses "stressed the basic facts," although 13 percent stated that this was overemphasized and 19 percent felt that courses "stessed fundamental ideas." 54/

a. Mathematics Requirements for High School Graduation

Weiss found through nationwide questionnaires that 21 percent of the States require more than one year of mathematics instuction for high school

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53/ Ibid., p. 13:24.

54/ Ibid.

graduation, 57 percent require one year, and 22 percent require less than one year. Seven percent of the States also indicated that they require specific mathematics courses to be taken, but none were listed. 55/

Nationwide enrollment patterns in high school mathematics courses have been found to be basically stable in recent years, although slight decreases were noted in some instances. 56/ In New York State, data from 1971-76 showed that, of 62 courses offered, a slight year-by-year enrollment decline was noted for "Math 7, 8, 10, 11, and 12; Algebra I and II; Trade and Shop Math; Advanced and Analytic Geometry; Problem Solving; and History of Mathematics." Enrollments of students in other courses indicated an "increasing trend." 57/

b. Changes in Mathematical Achievement

The National Assessment of Educational Progress (NAEP) conducted two surveys of the mathematical achievement of 9-, 13-, and 17-year-old students during the 1972-73 and the 1977-78 school years. Changes in students' performances between 1973 and 1978 were measured by providing exercises that helped determine mathematical understanding. Students were asked to "provide an explanation or illustration of different mathematical knowledges or skills, requiring a transformation of knowledge but not the application of that knowledge to solve a problem."

55/ Weiss, Iris R. Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education, p. 24. See appendix 1 for table.

56/ Suydam, Marilyn N., and Alan Osborne. The Status of Pre-College Science, Mathematics, and Social Science Education: 1955-1975. V. II, Mathematics Education, p. 44.

57/ Ibid.

Some of the results, which "should . . . be interpreted with caution [because] the items used to measure changes in achievement did not provide as broad of a coverage of the content of school mathematics as the entire 1977-78 mathematics assessment," are as follows: 58/

-. . . The overall results indicate that there has been some decline in mathematics achievement during the 1970s. [This may, however, reflect certain factors that affected student performance not strictly related to mathematics instruction];

-Changes in performance differed by age group, with declines becoming more apparent for the older students. Nine-year-olds showed very slight changes, with the exception of declines in the application area of problem solving, while 17-year-olds showed measurable drops in each of the cognitive process levels assessed--knowledge, skills, understanding, and application; and

-[There was] generally [a] low performance on problem-solving (application) items . . . . At each age, fewer students appeared proficient in solving problems deemed appropriate for their age level. For example, 9-year-olds' performance dropped considerably on several one-step word problems. Generally, fewer 13- and 17-year-olds could solve multistep, complex problems or could deal with topics such as percent and probability and statistics.

Panelists chosen to evaluate these results attribute the decline in problem solving to several factors:

-[T]he emphasis on "back-to-basics" [which] has often resulted in a narrowing of the curriculum, with more attention focused on computational skills and knowledge of facts and definitions and less time spent on problem solving;

-[T]extbooks that have come into widespread use during the 1970s have adopted a simplified approach to problem solving . . . . Often, all addition word problems are presented in the addition section of a textbook, all subtraction word problems in the subtraction section, and so forth, so that students do not gain experience in determining which operation is appropriate to the situation presented;

-[V]ocabulary in problems can cause difficulties. "If students aren't familiar with the vocabulary, they may not be successful in solving problems even though they may have mastered the necessary computational skills";

58/ National Assessment of Educational Progress. Changes in Mathematical Achievement, 1973-78: Results from the Second Assessment of Mathematics. Denver, Colorado, Education Commission of the States. Aug. 1979. p. 24-25.

> -. . . [T]he development of a mechanistic approach to problem solving. Teachers often try to train students to look for clues, or "key words," to decide which operation to use instead of encouraging students to think through the logic of the problem situation posed; and
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> -. . . [I]ncreased emphasis on testing brought about by demands for accountability and minimal competency has affected the mathematics curriculum. Increased testing may result in emphasis on areas that are easy to teach and easy to test . . . . "Rote drill and memorization can prepare students for certain types of tests, but problem solving demands more effort, both on the part of the teacher and the student." 59/

3. Scholastic Aptitude Test Scores

The Scholastic Aptitude Test (SAT) generally is taken by 11th and 12th grade high school students who are considering attending college, and specifically those colleges and universities that require applicants to take the test. It includes two parts, verbal and mathematical. The mathematical section calls for a general background in mathematics that is usually acquired from the first through the ninth grades, depends more on the reasoning ability than formal knowledge, and assesses the problem solving skills in three areas--"arithmetic reasoning, elementary algebra, and geometry." 60/ The verbal portion of the SAT measures "reading skills and word relationships." Scientific materials also are covered in this section of the test. Since 1963, there has been a notable decline in student SAT scores. From 1963 to 1977, there was a 49-point decrease in the average score on the verbal part (from 478 in 1963 to 429 in 1977) and a 32-point decline on the mathematical portion

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59/ Ibid., p. 25.

60/ College Entrance Examination Board. Advisory Panel on the Scholastic Aptitude Test Score Decline. On Further Examination. New York, College Entrance Examination Board, 1977. p. 3.

(from 502 in 1963 to 470 in 1977). 61/ Reasons for the decline during the 1960s have been attributed to a change in the "composition of students taking SATs." The continued drop in the 1970s is believed to be due to the increase in "electives in high school, declining academic standards, television viewing, and the changing role of the family." 62/

C. SUPPLY OF PRE-COLLEGE SCIENCE AND MATHEMATICS TEACHERS

The decline in SAT scores, along with the previously discussed general decrease in mathematical achievement as assessed by the NAEP, seems to be developing into a trend in a country "that seeks to maintain a lead in a technological era." In addition, "the quality of math- and science-oriented people are being drained from the field," according to a recent report. 63/ Larger salaries are being offered outside of the education field. For example, teachers can about double their salaries by working as "low level computer technicians." 64/ The National Council of Teachers of Mathematics (NCTM) states that, at the close of the 1977-78 school year, almost 10 percent of mathematics teaching positions in the Nation were vacant. 65/ The NCTM also stated that a change in the situation could not be expected within the next five years. 66/

61/ Ibid., p. 5.

62/ Ibid.

63/ Galambos, Eva C. Engineering and High Technology Manpower Shortages, p. 5.

64/ Walsh, Efthalia and John. Crisis in the Science Classroom. p. 22.

65/ National Council of Teachers of Mathematics. NCTM Documents Shortage of Mathematics Teachers. News Release, Oct. 19, 1978.

66/ Ibid.

"Unfilled teacher positions in mathematics and physical science evidently result both from a lessening in the attractiveness of science and mathematics teaching careers and from opportunities for more desirable employment outside of teaching," an NSF and Department of Education report has stated, although an ample supply of people with bachelor's and master's degrees in these fields seems to be available. 67/ In contrast, however, a report by the Southern Regional Education Board (SREB) has revealed that, in Virginia, there was a "gap of 38 percent between the number of openings [in 1979] for beginning math teachers [in high school] and the number of graduates prepared by colleges to teach the subject within the state." Furthermore, a North Carolina report "estimates an annual shortage of 300 [high school] math and science teachers, with the deficit becoming worse." 68/ The SREB concludes that the two current reasons for these shortages are the lure of higher paying non-teaching jobs, as stated above, and "a sharp decline in the number of majors in the discipline." 69/ The United States is graduating less than 1,000 persons per year who are trained to teach mathematics in the Nation's schools and the "picture for science teachers is almost a carbon copy of that for math." 70/

In spite of the fact that potential mathematics teachers do not all originate among mathematics majors, the National Education Association (NEA) estimated that a 12 percent national decline was evident within one year, 1978, of

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67/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 49.

68/ Galambos, Eva C. Engineering and High Technology Manpower Shortages. p. 6.

69/ Ibid.

70/ Scientific, Engineering, Technical Manpower Comments, v. 18, no. 10, Dec. 1981. p. 7-8.

graduates prepared to teach secondary school mathematics. 71/ Although the estimated supply of such graduates still exceeds the demand for the mathematics field, according to the NSF and Department of Education report, the NEA listed the mathematics field, along with "trade-industrial, agricultural, and science," as teaching areas on the "'tight' end of the scale." 72/ The Bureau of Labor Statistics has corroborated this opinion by reporting that mathematics teachers are being lured away by higher salaries in computer science areas. As salaries for computer personnel continue to increase, schools will find it more difficult to compete for these workers. 73/

Teachers of other subject areas, who are basically non-specialists in science and mathematics, usually are selected to help fill these vacant positions. 74/ The SREB Task Force on Higher Education in the Schools recommends that "states should develop an array of incentives to attract science and math teachers, including scholarships or loan programs for prospective teachers, tied to the teaching of these subjects within the state, following the established pattern of state subsidies to train medical personnel in short supply." 75/

71/ National Education Association. Teacher Supply and Demand in Public Schools, 1978. Washington, National Education Association, 1979. p. 4.

72/ Galambos, Eva C. Engineering and High Technology Manpower Shortages, p. 6.

73/ Howard, H. Philip, and Debra E. Rothstein. Up, Up, Up, and Away: Trends in Computer Occupations. Occupational Outlook Quarterly, v. 25, no. 2, Summer 1981. p. 7-8.

74/ Galambos, Eva C. Engineering and High Technology Manpower Shortages, p. 6.

75/ Scientific, Engineering, Technical Manpower Comments, v. 18, no. 10, Dec. 1981. p. 8.

III. COLLEGE-LEVEL SCIENCE AND ENGINEERING CONCERNS

A. UNDERGRADUATE SCHOOL

1. Science and Mathematics Majors

During the 1950s and 1960s there was a rapid growth in university science departments throughout the Nation. A main emphasis was placed upon preparing undergraduate students for graduate or professional study in both universities and four-year colleges, according to the NSF and Department of Education study. 76/ The study reports, however, that more students received "bachelor's degrees in science and mathematics than sought admission to graduate or professional schools." Some entered the labor market directly after graduation in science-related occupations, while others voluntarily sought other kinds of employment. This situation is still evident, the study contends, in spite of declining undergraduate enrollments in science and mathematics. In addition, "undergraduate science education has been criticized as being too theoretical and esoteric for most students, and still oriented toward those who are intent on graduate study." 77/ Therefore, it appears that the needs of the science majors who do not intend to enter graduate school and those who plan to pursue nonscientific careers are not being sufficiently met. 78/

76/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 39.

77/ Ibid.

78/ Ibid., p. 40.

2. Engineering Majors

Since 1973, undergraduate engineering school enrollments have almost doubled. 79/ In the fall of 1973, there were 186,705 total full-time undergraduate engineering students enrolled in the United States. In fall 1980, the number had grown to 365,117, a 95.6 percent increase. 80/ Many engineering schools are now finding it necessary to limit undergraduate enrollments. 81/ A survey conducted by the American Society for Engineering Education (ASEE) revealed that about "21 percent of 30 top engineering schools have restricted entrants and three more are considering doing so." 82/ The chart below shows a list of the schools that were limiting enrollments, considering limiting, or had not limited enrollments in early 1981.

79/ Peer, Elizabeth, and Lucy Howard. Help Wanted: Engineers. Newsweek, v. 96, Nov. 17, 1980. p. 87.

80/ Computed by CRS from unpublished data received from the National Center for Education Statistics.

81/ Engineering Crunch Seen Tightening. Engineering News-Record, v. 206, Apr. 30, 1981. p. 10.

82/ Ibid.

CHART 2

Schools Limiting Engineering Students

Limited

Univ. of California, Berkeley
U.C.L.A.
Univ. of Cincinnati
Cornell Univ.*
Univ. of Florida
Georgia Institute of Technology
Univ. of Illinois, Urbana-Champaign
Univ. of Maryland
Michigan State Univ.
Univ. of Michigan
New Jersey Institute of Technology*
S.U.N.Y., Stony Brook
Univ. of Notre Dame*
Ohio State Univ.
Univ. of Oklahoma
Penn State Univ.
Purdue Univ.
Virginia Polytechnic Inst. and State Univ.
Washington State University
Univ. of Wisconsin, Madison
Worcester Polytechnic Institute*

Considering limits
Univ. of Alabama
Univ. of Houston
Univ. of Texas, Austin

Not Limited
Carnegie-Mellon Univ.
Illinois Institute of Technology
Massachusetts Institute of Technology
Univ. of Missouri -Rolla
Univ. of Southern California
Stanford Univ.

*Limits apply throughout university.

Source: Engineering News-Record, v. 206, Apr. 30, 1981. p. 10.

The increased enrollments have been attributed to high starting salaries offered by various firms in industry to engineering graduates with bachelor's degrees. 83/ Because of the surge in engineering school enrollments, a large number of schools have tried to adjust to the problem by increasing teaching loads, eliminating certain courses, and hiring more faculty from foreign countries. Also, many schools have broadened the use of graduate teaching assistants or part-time faculty. 84/ At the University of Illinois (Champaign-Urbana), for example, Dean Daniel Drucker has been reported to be reducing

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83/ Peer, Elizabeth, and Lucy Howard. Help Wanted: Engineers, p. 87.

84/ National Science Foundation. Engineering Colleges Report 10% of Faculty Positions Vacant in Fall 1980. Science Resources Studies: Highlights, Nov. 2, 1981. p. 3.

enrollment by 20 percent to "relieve pressure on overworked faculty and crowded faculty and crowded laboratories." Many students are not being admitted. Those who are accepted, "score at the 97th percentile on entrance exams--a level Drucker finds 'ridiculously high for a public university.'" 85/

3. Non-Scientific and Technical Majors

Undergraduate science education has been found to be oriented toward students majoring in scientific areas who intend to pursue advanced graduate degrees. The needs of those science majors who plan to enter the labor force upon graduation and those who do not plan to seek scientific careers appear not to be adequately considered, according to the NSF and Department of Education report. 86/ Furthermore, it was found that there is no general agreement regarding what information should and should not be included in science and mathematics courses for non-technical majors. 87/ Many colleges and universities generally offer less rigorous and more descriptive courses for these students than for science majors. It also was stated that a large number of such students tend to avoid the more rigorous subjects because such courses are considered to be more difficult. Therefore, in many cases a considerable number of college-level students do not receive exposure to science and mathematics courses beyond 10th grade biology and 10th grade geometry. 88/

85/ Samuelson, Robert J. Engineering Enigma. National Journal, v. 13, Dec. 12, 1981. p. 2206.

86/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 40.

87/ Ibid.

88/ Ibid.

A National Research Council (NRC) Committee for a Study of the Federal Role in the College Science Education of Non-Specialists has studied the situation of non-science and technical college majors and has concluded that science education for non-specialists is deteriorating. 89/ The Committee contends that the "enlightened non-specialist" can make significant contributions to "help implement the pluralist function of democratic decisionmaking about pressing" science and technology concerns; "serve as opinion leaders in the American structure to help the public at large understand the complexities as well as the risks and benefits of science and technology"; and "lead the way in their professions more effectively if they have a command of science and technology." 90/

The following findings were reported as evidence that the majority of the Nation's institutions of higher learning are not providing the type of scientific and technical education that the NRC Committee believes is essential for non-specialists, in order for them to function effectively in society. 91 /

-The historical evolution of college science education has benefited the science major immensely but has left the non-specialist largely unattended;

-Colleges and universities in general have lowered their science requirements over recent years to the alarming point where the average non-specialist student devotes only about 7 percent . . . of a college course load to work in the sciences;

-Within such subminimal requirements, these students are often allowed to choose willy-nilly from an ever-growing cafeteria offering "topics courses" that rarely fit into a well-conceived, comprehensive pattern of education;

-In many cases, those topics courses, which were designed as a response to the student concern for relevancy in the 1960s, have outgrown their relevancy;

-In all too many other cases, those topics courses, as they reach for relevancy, fail to provide students with an understanding of the basic principles of science;

89/ National Research Council. Science for Non-Specialists, p. xii.

90/ Ibid., p. xii-xiii.

91/ Ibid., p. xi-xii.

-When students do opt for more traditional introductory science courses, learning often suffers because so many students come to college ill-prepared in secondary-school science and mathematics; and

-These students often are subjected to inadequate teaching that stresses dull lecturing more often than exciting laboratory experiments and demonstrations.

The American Association for the Advancement of Science (AAAS) conducted a survey among non-science majors 92/ and found that many are not necessarily uninterested in scientific subjects. Over 500 U.S. colleges and universities were located that offer courses that examine the relationship between science, technology, and society or provide courses in the history or sociology of science. 93/ Several of the programs were found to be cooperative ventures "between science or engineering, and social science and/or humanities departments." Through analyzing course enrollments, it was found that the response of students were usually moderately good. After examining the AAAS survey, the NSF and Department of Education study concluded, however, that "[the] apparent relative [course] popularity is a positive development," but "few such courses lead to familiarity or competence with the concepts and processes of science and technology themselves." 94/

The NRC Committee suggested several goals that U.S. colleges and universities could set that might improve undergraduate science education for non-specialists. They are: 95/

92/ American Association for the Advancement of Science. EVIST Resource Directory: Ethics and Values in Science and Technology. Office of Science Education. Washington, 1978. AAAS Publication, 78-6. 208 p.

93/ Ibid., p. v.

94/ National Science Foundation and Department of Education. Science and Engineering Education, p. 40.

95/ National Research Council. Science for Non-Specialists, p. xiii.

-College science education should enable non-specialists to overcome fears that might prevent them from launching a lifetime learning experience about science and technology;

-. . . [E]nable non-specialists to develop their capacity to engage in critical thinking;

-. . . [E]nable non-specialists to know how to seek reliable sources of scientific and technical information and how to use them throughout life;

-. . . [E]nable non-specialists to gain the scientific and technical knowledge needed in their professions; and

-. . . [E]nable non-specialists to gain the scientific and technical knowledge needed to fulfill civic responsibilities in an increasingly technological society.

The NRC Committee suggests that college and university science faculties have the major responsibilities of preparing students to reach these goals. These faculties need the assistance, the NRC Committee stated, of other institutions and agencies such as State governments, private foundations, industry, and the Federal Government. 96/

Testifying at hearings before the House Committee on Science and Technology, 97/ John W. Geils, staff executive of the ASEE, reported that the Council for the Understanding of Technology in Human Affairs (CUTHA), an organization created in 1980 that is composed of over 100 U.S. colleges and universities, is "attempting to get liberal arts faculties to understand and teach the importance of technology in today's human environment. Only through real improved understanding," Mr. Geils suggested, "can tomorrow's lay civic leaders make intelligent decisions concerning energy, environment, genetics, sophisticated weapons systems, [and] the impact of computers . . . ."

96/ Ibid.

97/ U.S. Congress. House. Committee on Science and Technology. Engineering Manpower Concerns. Hearings, 97th Cong., 1st Sess. Washington, U.S. Govt. Print. Off., 1981. p. 25.

4. The Level of Scientific and Technical Competence of the U.S. Population

The state of pre-college science and mathematics education and college-level science education for non-science majors are among the reasons 98/ for recent concern about the level of scientific and technical literacy of many college graduates and the general U.S. population.

An NSF survey has found that the public attitude toward science and technology is basically favorable. The general understanding about the "substance of science and the methods by which scientists seek to answer questions," however, is slight. 99/ It was concluded by one NSF analyst that "probably not more than 12 percent of the [U.S.] adult population really understands what is meant by the scientific approach." 100/ It was determined in a report prepared for the NSF, that "the level of [an individual's] understanding of science is directly related to the level of education attained." 101/ Furthermore, this is not just the case with science. Information obtained through national public opinion polls have revealed that:

> . . . [The] results of all . . . the information questions on public events, history, geography, and other topics including health and science are all consistent: college graduates know more than high school graduates, and high school graduates know more than elementary school graduates. This relationship holds regardless of age, sex, or family background. It is true for information normally learned in school and for information not

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98/ See also part IV, Introduction.

99/ Wolfle, Dael. Public Policy Decisionmaking and Scientific Literacy. Prepared for the National Science Foundation. Papers Commissioned As Inputs to Second Annual Science and Technology Report (ASTR). v. VI, Public Policy Decisionmaking and Science Literacy: Information Needs for Science and Technology. Washington, U.S. Dept. of Commerce, National Technical Information Service, 1980. p. 13.

100/ Ibid., p. 14.

101/ Ibid.

> normally learned in school. Persons with more formal education continue to learn more during their adult lives than do persons whose schooling stopped at an earlier age. 102/

Results of National Assessment of Educational Progress studies, discussed previously, have shown a general decline in scientific knowledge of 9-, 13-, and 17-year-olds. This was determined through the decrease in average test scores, between 1969 and 1972, for answers to questions about physical and biological science. From 1972 to 1976, average scores for 17-year-olds continued to decline, while averages remained basically the same for 9- and 13-year-olds. Measurements of mathematics achievement between 1973 and 1978 showed a decline for all age groups. 103/ This decrease in knowledge, it has been concluded, is "consistent with other evidence that many children are not learning as well in school as their predecessors of 10 to 30 years earlier." 104/ By 1979, the high school seniors surveyed had joined the general workforce or become college attendees. Within the decade or less, the 9- and 13-year-olds will be in the same or similar positions. If the trend of underachievement continues, the cycle of scientific illiteracy in the Nation may be perpetuated.

Various means that could be used to help improve the public's scientific literacy have been studied--the news media, magazines, newspapers, and television. Effective programs, however, probably would require long-term and continuing commitments of these media, scientific organizations, the Nation's schools, and other nonprofit associations related to medicine, science, and education to produce any important changes. 105/ In addition, the amount of

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102/ Ibid.

103/ Ibid.

104/ Ibid., p. 15.

105/ Ibid., p. ii.

education and interests that individuals already have attained has an important bearing on who would "take advantage of opportunities for continuing education, self study, and other means of learning." Therefore, an important conclusion is that the people who would gain significantly from these efforts to improve science literacy would be those who are already fairly literate. 106/

B. GRADUATE SCHOOL

1. Science and Mathematics Departments

Throughout the 1950s and 1960s, there was a rapid growth in university facilities, in addition to rising undergraduate and graduate enrollments resulting in a rapid expansion of university science faculties, the creation of new Ph.D. programs in many schools, and the advancement of a large number of young college teachers to tenured rank, most of whom are due to retire around 1990. 107/ Also during this time, university science and mathematics graduate level courses had been structured to prepare students for teaching positions and research. In the early 1970s, however, the "sizes of science and mathematics faculties began to stabilize and, in some cases, to decrease as Federal research support declined and the growth rate of undergraduate enrollments slowed down. As a result, junior faculty positions have become relatively scarce, particularly in physics and mathematics and most of the social sciences." 108/ For this reason, there is concern that because of

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106/ Ibid., p. 20.

107/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 38.

108/ Ibid.

the recent decline in Ph.D. enrollments in the mathematical, physical, and life sciences, there may not be sufficient numbers of qualified individuals to fill vacant faculty positions that will be the result of the anticipated large scientific faculty retirements by the mid-1990s. 109/ Furthermore, "the fact that many science and mathematics departments cannot bring in 'new blood' could hamper their ability to provide innovative instruction and research opportunities to their students." 110/

2. Engineering Graduate Students

In contrast to the increased undergraduate student enrollments in engineering, graduate engineering school enrollments are decreasing. 111/ The proportion of engineering school graduates who pursue advanced degrees in engineering, specifically the doctorate, has "fallen from an average level of about 11 percent in the 1970s to only about 5 percent" in 1980. 112/

Data from the Engineering Manpower Commission (EMC) shows that in fall 1980, there was a total of 44,335 full-time engineering students enrolled in graduate school. Compared with 38,381 in fall 1978, this is a 15.5 percent increase in enrollment, and a 7.1 percent increase over fall 1979 (41,384). 113/ Nevertheless, the National Center for Education Statistics projects that

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109/ Ibid.

110/ Ibid.

111/ Willenbrock, F. Karl, and Cecil H. Green. United States and Technological Preeminence. Science, v. 213, Sept. 18, 1981. p. 1319.

112/ One tenth of Engineering Faculty Slots Vacant. Chemical and Engineering News, v. 59, Nov. 30, 1981. p. 30.

113/ Actual enrollment numbers were obtained from the EMC during a telephone conversation on Jan. 6, 1982.

there will be a continual decrease in the number of Ph.D. degrees awarded in engineering from 1978 to 1989. 114/

The reason for this decline has been attributed to large salaries being offered by industry to engineering bachelor's degree recipients. The differences between industry salaries and academic salaries may be discouraging many students from seeking advanced degrees and eventually teaching in college and university faculties. 115/ Daniel Drucker, President of the American Society for Engineering Education, has estimated that "15 percent of the top engineering graduates [enroll] in graduate programs." "The figure," he concludes, "should be at least 35 percent." 116/

C. ENGINEERING FACULTY SHORTAGE

One-tenth of the 16,200 full-time engineering faculty positions in the Nation were unfilled at the beginning of the 1980-81 academic year, according to an NSF Highlights report. About two-fifths of these positions had gone vacant for at least one year. By field, 13 percent of unfilled industrial engineering faculty positions and 16 percent of the computer science/computer engineering unfilled faculty positions represent the highest vacancy levels. 117/

Large starting salaries offered by various industries to recent bachelor's degree graduates, as previously stated, generally have been given credit for

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114/ National Science Foundation. Engineering Colleges Report 10% of Faculty Positions Vacant, p. 3.

115/ Peer, Elizabeth, and Lucy Howard. Help Wanted: Engineers, p. 87.

116/ McCurdy, Jack. Faculty Shortage Perils Engineering Schools' Growth. Chronicles of Higher Education, v. 22, June 29, 1981. p. 1, 5.

117/ National Science Foundation. Engineering Colleges Report 10% of Faculty Positions Vacant, p. 1.

luring potential engineering Ph.D. recipients and future faculty members away from academic careers. An NSF survey conducted by the American Council on Education has revealed that a large number of deans at various engineering schools are in agreement with this statement. 118/ In fact, it was reported that "it would have taken most of the 2,753 engineering Ph.D.'s awarded in 1980 just to fill currently vacant engineering faculty positions." 119/

The Scientific Manpower Commission (SMC) reports that the average 1981 starting salaries for petroleum engineers with a bachelor's degree was $26,650, an 11.8 percent increase over the average starting salary offered in 1980 ($23,840); a bachelor's level chemical engineer's average starting salary was $24,360, a 12.7 percent increase over 1980 ($21,612); 120/ for an electrical and computer engineer, the average starting salary was $22,584; a computer scientist began with an average salary of $20,712. 121/ For individuals with master's degrees in chemical engineering, the average starting salary was $26,484; $25,656 for a master's level electrical and computer engineer; compared with $32,940 for a doctorate degree recipient in chemical engineering, and $33,516 for a Ph.D. level electrical and computer engineer. 122/

118/ Ibid., p. 3.

119/ One tenth of Engineering Faculty Slots Vacant, p. 30.

120/ In early 1982, the SMC reports that starting salaries have increased for petroleum and chemical engineering by 12 and 10.2 percent, respectively. Petroleum engineering has the highest average monthly salary offer of $2,488. Chemical engineering is second with $2,236 per month. Scientific, Engineering, Technical Manpower Comments, v. 19, no. 1, Jan./Feb. 1982. p. 11.

121/ Babco, Eleanor. Salaries of Scientists, Engineers and Technicians: A Summary of Salary Surveys. 10th ed. Washington, Scientific Manpower Commission, Nov. 1981. p. 4.

Starting salaries for computer scientists, in early 1982, increased compared with the July 1981 level. The average monthly salary offer now is $1,785 per month, as opposed to $1,736 in July 1981, as recorded in the above cited Eleanor Babco report, p. 5.

122/ Ibid., p. 8.

Along with differences in salaries offered by industry and academia, difficulty in obtaining tenure also has been noted as a deterrent, for some new bachelor's degree holders, to pursuing academic careers. In academia, an individual with a doctorate generally begins as an assistant professor, teaches for about six years, and only then is advised as to the status of his or her job. The average salaries for full-time engineering faculty members for a nine month period for fall 1981, were as follows: 123/

Assistant Professor -- $24,100

Associate Professor -- $28,100

Full Professor -- $35,300

Experienced engineering faculty members also have been lured away by industry. 124/ In 1980, about three percent of full-time faculty members in permanent positions voluntarily left for jobs in industry. Only engineering faculty who worked in the field of computer science had a significantly high mobility rate, of about 5.6 percent, the survey indicated. 125/

According to Daniel Drucker, President of the ASEE, "the need for engineering professors 'is going to get worse and the quality of instruction will continue to degrade . . . .' The problem is not just that too few engineers

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123/ Provided during a telephone conversation with John W. Geils, Staff Executive with the American Association of Engineering Societies.

124/ National Science Foundation. Engineering Colleges Report 10% of Faculty Positions Vacant, p. 3.

125/ Ibid.

are going on to graduate school, but that 'far too many of the best graduates are not going on.'" 126/ As a result, there is also a shortage of teaching assistants. 127/

The Accreditation Board for Engineering Technology (ABET), affiliated with the American Association of Engineering Societies (AAES), has been reported to have "granted full six-year accreditation to only 56 percent of the [engineering college and university] curricula it evaluated in the past year. The remaining 44 percent received a conditional three-year accreditation or were denied it." 128/ Leland Walker, the president of ABET, is reported to consider this "relatively low percentage of full accreditation as a sign of deterioration in education quality." The decline he has stated, "is showing itself in faculty shortages, obsolescence of laboratory equipment and oversized classes." 129/ Dr. John C. Hancock, Dean of Engineering at Purdue University, expressed a similar concern when he stated at the recent IEEE Spectrum meeting that "there are people being placed on university faculties today that 10 years ago we would never have considered . . . they are going to get tenure because the shortage is going to continue. Substandard teachers," he also pointed out, "turn out substandard engineering graduates." 130/

126/ McCurdy, Jack. Faculty Shortage Perils Engineering School's Growth, p. 1.

127/ National Association of State Universities and Land-Grant Colleges. Committee on Energy and Environment, Commission on Education for the Engineering Professions. The Doctoral Shortage in Engineering: A Growing Crisis. A Policy Paper. Washington, Oct. 26, 1981. p. 10.

128/ Engineering Crunch Seen Tightening, p. 10.

129/ Ibid.

130/ Perry, Tekla S. Engineering Education: Coping With the Crisis. IEEE Spectrum, v. 18, Nov. 1981. p. 67.

Possible solutions to this situation were considered by various panelists at the IEEE Spectrum meeting. One suggestion was to raise faculty salaries. Dr. Paul E. Gray, President of the Massachusetts Institute of Technology (MIT), stated that "we have to be able to increase engineering faculty salaries and be prepared to do that in the face of all the economic pressures universities are facing and also in the face of increasingly bitter complaints from faculty elsewhere that 'this is not fair; you are raising those folks' salaries faster than mine.'" 131/ Dr. Herbert H. Woodson, chairman of the Electrical Engineering Department at the University of Texas, stated that this was not a serious problem at his university. Engineering faculty members received a small increase in January 1981, he reported, that was not given to other faculty members. There were some "disgruntled faculty in the other colleges," he admitted, but this did not "cause any real problems." 132/

In 1981, the University of Minnesota was reported to have increased engineering school tuition costs at about $250 per semester in order to raise engineering faculty salaries. Richard J. Gowen, Dean of Engineering at the South Dakota School of Mines and Technology, has stated that "his school and several others have made similar tuition increases and are channeling the money almost entirely into faculty salaries." 133/

Finding the necessary funds to increase engineering faculty salaries was debated at the IEEE Spectrum meeting. Dr. Gray stated that the extra stipend should come from endowments and tuition because "the salary differential has to be permanent." 134/ Other participants discussed assistance from sources outside the academic setting. Dr. George A. Keyworth, the President's science adviser,

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131/ Ibid.

132/ Ibid., p. 68.

133/ One tenth of Engineering Faculty Slots Vacant, p. 30.

134/ Perry, Tekla, S. Engineering Education, p. 68.

dismissed possible financial assistance from the Federal Government because of the "economic views of the present Administration." He suggested, however, two alternatives for assistance--industry, and the Department of Defense (DOD). He stated that the DOD could "allow a portion of research grant money to increase salaries 40 percent." 135/ Dr. Hancock, Dean of Engineering at Purdue University, did not agree with this suggestion. He stated that grant money could not be used to raise salaries. 136/ Dr. William J. Perry, former DOD Under Secretary of Research and Engineering and currently chairman of a committee of electronics industry leaders coordinated by the American Electronics Association (AEA), stated that the AEA could recommend that its member companies hire new university engineering instructors as part-time consultants. "Most . . . professors with 10 to 15 years of tenure have all the consultancies they want," he stated, "but entry-level instructors don't. If we can package something so the university can offer the instructor a job with a guaranteed consultancy, that would go a long way toward dealing with the faculty issue." 137/

The Exxon Corporation recently announced a plan to provide $15 million in grants to help allay the problem of the developing engineering faculty shortage. The money would guarantee 100 teaching fellowships that would be "three-year grants totaling $40,500 to cover tuition, fees and living stipends for recipients," and 100 salary support grants to engineering faculty at 66 colleges and universities in an effort to encourage more engineering graduates to pursue careers in academia. 138/ The support grants would be "five-year, $100,000 awards to

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135/ Ibid., p. 69.

136/ Ibid.

137/ Ibid.

138/ Exxon Announces $15 Million for Engineering Education. Higher Education Daily, v. 9, Sept. 21, 1981. p. 5.

engineering departments designed to keep junior faculty in teaching 'when they are most vulnerable to job offers from industry.'" 139/

D. STATE OF UNIVERSITY LABORATORY EQUIPMENT

The average age of most college and university equipment in science and engineering laboratories exceeds 14 years. 140/ Another source claims that at many universities much equipment dates from World War II. 141/ According to many experts, aging laboratory equipment and facilities have been a deterrent to students in seeking advanced degrees and academic careers. In addition, it has been stated that many "engineering professors leave their academic posts because industry provides them with more exciting and challenging research opportunities." 142/

The NSF and the Department of Education report states that "equipment-intensive research areas such as physics, engineering, chemistry, and the life sciences have experienced a decade in which the development, purchase, and maintenance costs of instrumentation have escalated rapidly, while the state-of-the-art apparatus, needed to conduct research at the cutting edge of science, has become increasingly sophisticated--and expensive." 143/ Federal funds for university research equipment declined in the 1970s, the report states, and

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139/ Ibid.

140/ Scientific, Technical, Engineering Manpower Comments, v. 18, no. 2, Mar. 1981. p. 7.

141/ Reinhold, Robert. View From the Lab: Prospects Are Glum for Engineers. The New York Times, Dec. 23, 1980. p. C1.

142/ Scientific, Technical, Engineering Manpower Comments, v. 18, no. 9, Nov. 1981. p. 5.

143/ National Scientific Foundation and Dept. of Education. Science and Engineering Education, p. 39.

equipment costs exceeded inflation levels. Industrial laboratories, by contrast, have been updated continuously with necessary scientific apparatus. 144/ To help remedy part of the problem of obsolete university laboratory equipment, the study suggests that there be "greater flexibility in Federal research grant and contract administration that would encourage pooling of equipment funds and sharing apparatus between university departments; further development of regional instrumentation centers; and enhanced university-industry cooperation." 145/

In 1981, the NSF made 235 awards, through its Instructional Scientific Equipment Program, to colleges and universities in 45 States and the District of Columbia. The awards totaled $3 million for the purchase of laboratory equipment to help improve undergraduate science and engineering education in the Nation. 146/ The program is designed to "strengthen classroom, laboratory and field work experience for undergraduate students by exposing them to up-to-date laboratory instrumentation and current educational technology." Colleges and universities receiving the awards were asked to match or exceed the Foundation's contribution. This brought the total investment to over $6 million in equipment.

144/ Ibid.

145/ Ibid.

146/ Muldoon, Richard. NSF Awards $3 Million to Colleges and Universities for Instructional Scientific Equipment. National Science Foundation News Release, Sept. 17, 1981. p. 1.

At NSF Authorization Hearings, FY 1983, held Mar. 4, 1982, by the House Committee on Science and Technology, Subcommittee on Science, Research, and Technology, the question was raised regarding whether the NSF has a way of determining if funding designated for purchasing new laboratory equipment is actually used for that purpose. Dr. Donald Langenberg, Deputy Director of the NSF, responded that NSF does not have such a method. The concern was that some equipment may be undergoing repairs instead of being replaced by new equipment. For fiscal year 1983, the NSF has stipulated $95.3 million for improvement of instrumentation.

IV. STATUS OF SCIENCE AND ENGINEERING MANPOWER

A. THE SUPPLY OF RECENT COLLEGE GRADUATES IN SCIENCE AND ENGINEERING FIELDS

Concern about the current availability of scientific and engineering degreed personnel for employment has become evident because there appears to be shortages of qualified individuals occurring in some engineering fields, subspecialty scientific fields, as well as in college and university engineering faculties.

Data are provided below that show recent undergraduate and graduate degrees awarded in several scientific and engineering fields.

1. Undergraduate Degrees Awarded in Several Scientific Fields

Dr. John B. Slaughter, Director of the National Science Foundation, has stated that "we have current personnel shortages at almost every degree level and in nearly every specialty of engineering and the computer professions, as well as in certain professions of the physical and biological sciences--geology, for example." 147/ It appears, however, that shortages in scientific areas may not be as critical as those in some areas of the engineering profession since (1) job openings for doctoral faculty members in mathematics, physical science, the biological and social sciences, for example, currently are scarce 148/; and (2) there appears to be large numbers of qualified physicists, chemists, mathematicians,

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147/ Perry, Tekla S. Engineering Education, p. 68.

148/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 25.

and biologists available. The numbers of undergraduate degrees awarded in 1978 through 1980 are shown in table 1 below.

TABLE 1. Total 1978-1980 Bachelor's Degrees Awarded in Selected Scientific Fields

	1978	1979	1980
Total, all fields, including science and engineering	930,201	921,390	929,417
Biological Sciences, Total	52,213	48,846	46,370
Physical Sciences, Total	23,175	23,207	23,410
Computer and Information Sciences, Total	7,224	8,769	11,213
Mathematics, Total	12,701	11,806	11,378

Source: Compiled by CRS from 1979 and 1980 unpublished data received from the National Center for Education Statistics, and from 1978 data in U.S. Dept. of Education. National Center for Education Statistics. Earned Degrees Conferred, 1977-78. Washington, U.S. Govt. Print. Off., 1980. p. 28-31.

The data indicate that there was a 10 percent decrease in all undergraduate degrees awarded between 1978 and 1979. In the specific scientific fields listed, there was a 7 percent decline in total biological science degrees awarded between 1978 and 1979, and a further decline of 5.3 percent between 1979 and 1980; an 8 percent drop in total mathematics degrees awarded between 1978 and 1979; and a 3.8 percent additional decline between 1979 and 1980. The other fields listed--physical sciences and computer and information sciences--indicate slight increases in degrees awarded--a 0.13 percent increase in total physical science degrees awarded between 1978 and 1979, and a 0.9 percent increase between 1979 and 1980; and a 21.3 percent increase in computer and information sciences degrees between

1978 and 1979, and a 27.8 percent increase between 1979 and 1980. Computer science is one of the fields in which personnel is in great demand. This may be one of the reasons for the significant increases in bachelor's degrees in this area. 149/

2. Undergraduate Degrees Awarded in Engineering Fields

A notable increase has been reported in the number of recent engineering graduates at the bachelor's degree level. 150/ This is believed to be because of the recent large undergraduate enrollments in engineering schools. The National Center for Education Statistics (NCES) of the Department of Education notes that in 1979, 62,375 engineering students received bachelor's degrees, and in 1980, 68,893 bachelor's degrees were awarded, a 10.4 percent increase. 151/

Table 2 below shows the total number of bachelor's degrees awarded in various engineering fields from 1978 to 1980.

TABLE 2. Total 1978-1980 Bachelor's Degrees Awarded in Various Engineering Fields

	1978	1979	1980
Total, all fields, including science and engineering	930,201	921,390	929,417
Engineering, Total	56,009	62,375	68,893
Aerospace, Aeronautical Astronautical Engineering	1,186	1,386	1,424
Bioengineering and Biomedical Engineering	350	422	395

149/ See Section B below, The Demand of Recent College Graduates in Science and Engineering Fields, p. 66.

150/ Dickson, David. U.S. Graduate Salaries: Engineers Ahead. Nature, v. 292, Aug. 20, 1981. p. 663.

151/ Computed by CRS from NCES 1979 and 1980 unpublished data.

TABLE 2. Total 1978-1980 Bachelor's Degrees Awarded in Various Engineering Fields (cont.)

	1978	1979	1980
Chemical Engineering	4,615	5,568	6,320
Civil, Construction, and Transportation Engineering	9,265	9,809	10,326
Electrical, Electronics, Communications Engineering	11,213	12,338	13,821
Geological Engineering	157	191	222
Geophysical Engineering	56	36	56
Industrial and Management Engineering	2,712	2,785	3,175
Mechanical Engineering	8,924	10,107	11,808
Nuclear Engineering	545	787	893
Other Engineering	13,396	18,099	19,958

Source: National Center for Education Statistics.

Total bachelor's degrees awarded in engineering have increased by 23 percent since 1978. All other bachelor's engineering degrees listed show increases, although some are relatively small in absolute numbers. For example, aerospace, aeronautical, and astronautical engineering rose by 38, and geological engineering increased by 31, from 1979 to 1980. More bioengineering and biomedical engineering bachelor's degrees were conferred in 1979, a 20.5 percent increase over 1978, than in 1980, which showed a 6.8 percent decline. Fifty-six bachelor's degrees were awarded in geophysical engineering in 1978. This dropped to 36 in 1979, but increased back to 56 in 1980. This no-growth situation in geophysical degrees may indicate a shortage in this area on the undergraduate degree level. Other factors, however, may also be relevant to the small numbers. Nuclear engineering bachelor's degree recipients have continued to diminish since 1978. In 1979, there was a 6.2 percent decline in such degrees awarded, and a further 3.6 percent decrease in 1980. It has been reported that the Department of Energy predicts future shortages in nuclear engineering because several universities are eliminating nuclear engineering departments and more plan to do so. 152/

3. Advanced Degrees Awarded in Various Scientific Fields

Dr. George A. Keyworth, the President's science adviser, has stated that "many industrialists are finding that they cannot get Ph.D.s when they need them." 153/ This problem, he indicated at the IEEE *Spectrum* meeting, reflects the "deterioration of academic life." He also stated that most students who go after a Ph.D. do so because it ensures the possibility of pursuing an academic career, so if they see an academic career as unattractive, at least half the motivation for a Ph.D. disappears. 154/ Dr. John C. Hancock, Dean of Engineering at Purdue University, stated at the same meeting that "industry was not signaling to students that they needed [the Ph.D.]. Rather students get the impression that they need only a B.S., and perhaps an M.B.A. later, as they work their way into management." 155/ The President of Exxon Research and Engineering, Dr. Edward E. David, added that "there was a need in industry for advanced degree holders 'who understand how to design in an overall systems context, as opposed to

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152/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 28.

153/ Perry, Tekla S. Engineering Education, p. 66.

154/ Ibid.

155/ Ibid.

designing a box or a piece.'" Bachelor's degree graduates, specifically in engineering, do not have this "broad view." 156/

Table 3, below, shows the number of various scientific master's and doctoral degrees awarded from 1978 through 1980.

TABLE 3. Total 1978-1980 Master's and Doctorate Degrees Awarded in Various Scientific Fields

	1978		1979		1980	
	M.S.	Ph.D.	M.S.	Ph.D.	M.S.	Ph.D.
Total, all fields, including science and engineering	312,816	32,156	301,079	32,730	298,081	32,615
Biological Sciences, Total	6,851	3,313	6,831	3,542	6,510	3,636
Physical Sciences, Total	5,576	3,137	5,451	3,102	5,219	3,089
Computer and Information Sciences, Total	3,038	196	3,055	236	3,647	240
Mathematics, Total	3,383	805	3,036	703	2,860	724

Source: National Center for Education Statistics

Total master's degrees awarded in all scientific fields show a decline--in 1979, there was a 3.9 percent decline over 1978, and a slight decline of 1 percent in 1980 over 1979. On the Ph.D. level, total degrees awarded in 1979 showed an increase by 1.8 percent, but had a small decline by 0.4 percent in 1980. Of the scientific fields listed, there were decreases in all fields in at least one degree level except in the computer and information sciences where there were increases on both degree levels for 1979 and 1980. Total degrees awarded in the physical science field declined at both degree levels in 1979 and 1980. In the

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156/ Ibid.

biological sciences and mathematics areas there were drops in master's degrees awarded in 1979 and 1980, but increases at the Ph.D. levels. In mathematics, specifically, Ph.D.s awarded in 1979 declined by 15 percent from 1978, but increased 3 percent in 1980, indicating, however, an overall 12 percent decline in the number of degrees awarded since 1978.

4. Advanced Degrees Awarded in Various Engineering Fields

Table 4, below, provides the number of engineering graduates awarded master's and doctoral degrees from 1978 to 1980 in several engineering disciplines.

TABLE 4. Total 1978-1980 Engineering Master's and Doctoral Degrees Awarded in Various Engineering Fields

	1978		1979		1980	
	M.S.	Ph.D.	M.S.	Ph.D.	M.S.	Ph.D.
Total, all fields including science and engineering	312,816	32,156	301,079	32,730	298,081	32,615
Engineering, Total	16,409	2,440	15,495	2,506	16,243	2,507
Aerospace, Aeronautical, Astronautical Engineering	411	115	372	95	382	99
Bioengineering and Biomedical Engineering	191	61	189	50	209	49
Civil, Construction, and Transportation Engineering	2,691	277	2,646	253	2,683	270
Electrical, Electronics, Communications Engineering	3,742	503	3,591	586	3,836	525
Geological Engineering	52	---	27	3	36	2
Geophysical Engineering	19	1	16	1	16	4
Industrial and Management Engineering	1,722	118	1,502	149	1,313	116

TABLE 4. Total 1978-1980 Engineering Master's and Doctoral Degrees Awarded in Various Engineering Fields (cont.)

	1978		1979		1980	
	M.S.	Ph.D.	M.S.	Ph.D.	M.S.	Ph.D.
Mechancial Engineering	1,943	279	1,877	271	2,060	281
Nuclear Engineering	494	112	401	91	365	49
Petroleum Engineering	98	21	127	24	122	25
Other Engineering	3,809	694	3,598	679	1,948	326

Source: National Center for Education Statistics

The Wall Street Journal reports that the number of doctorates awarded in engineering has dropped 25 percent within the last decade. 157/ Since 1978, however, total engineering Ph.D. degrees awarded, as indicated by NCES data, have increased by 2.7 percent in 1979, and a further 0.04 percent in 1980. Doctoral degrees awarded in certain engineering subspecialty areas listed above, however, have declined--no Ph.D. degrees were awarded in geological engineering in 1978, three were conferred in 1979, and only two given in 1980; one Ph.D. degree was awarded in geophysical engineering in both 1978 and 1979. The number increased to four in 1980.

According to a report by the National Association of State Universities and Land-Grant Colleges,

> The production of engineering doctorates in the U.S. is far short of requirements. This shortage threatens to undermine (1) the strength of our basic industries; (2) our ability to compete in world markets; (3) our capacity to foster defense-related technologies; (4) our creativity for new materials and industries; and (5) the fundamental capability of our universities in teaching and research. 158/

157/ Lowenstein, Roger. Two-Edged Sword: Surge in Engineering Enrollments Begins To Ease Industry's Shortages But Stirs Trouble at Colleges. The Wall Street Journal, Aug. 20, 1981. p. 52.

158/ National Association of State Universities and Land-Grant Colleges, p. 1.

B. THE DEMAND FOR RECENT COLLEGE GRADUATES IN SCIENCE AND ENGINEERING FIELDS

The Scientific Manpower Commission reports that there is an extensive demand for professionals in engineering and computer science. According to the SMC, a survey conducted by the Fox-Morris Personnel Consultants of Delaware found, for example, that the overall demand for electrical and electronic engineers increased 2 percent from early 1981 to the same time in 1982. In addition, electrical/electronic and mechanical engineers head the demand for engineers with 2 to 5 years experience. During 1982, such experienced personnel and new graduates will be sought mostly in electrical, mechanical, and chemical engineering. 159/

BLS spokesmen report that there are not enough computer specialists graduating from colleges and universities to meet the current demand. 160/ "Graduates of programs in computer science are filling 1 out of 6 [available] jobs at the bachelor's level, 1 out of 11 jobs at the master's level, and 1 out of 4 jobs at the doctor's level. 161/

A Scientific Manpower Commission staff member has stated that it is unclear whether there is a shortage at the undergraduate level in computer science, but it is clear that there is one on the graduate level. Computer scientists, especially programmers, are in great demand, but the supply is inadequate to meet that demand. This situation shows no sign of improving, the spokesman indicated, because the "computer world" is advancing at such a rapid pace. 162/

159/ Scientific, Engineering, Technical Manpower Comments, v. 19, no. 1, Jan./Feb. 1982, p. 3.

160/ Computer Occupations. Occupational Outlook Quarterly, v. 25, no. 2, Summer 1981. p. 24.

161/ Ibid.

162/ Discussed during a telephone conversation with Betty Vetter of the SMC on Nov. 30, 1981.

The SMC reports that this demand is about 20 to 40 percent greater than the supply. Recent graduates cannot fill "even the present demand for systems analysts and programmers." This has resulted in "students with majors in other fields who have completed computer science courses in college also . . . finding jobs in this area." 163/

The Fox-Morris Personnel Consultants survey found that the demand for all disciplines of the computer profession will be up 19 percent in 1982, over 1981, with the demand for computer programmers even higher, showing an increase of 21 percent compared with 1981 levels. 164/ Other computer specialties in great demand, they note, are "systems analysts, telecommunication specialists, auditors with data processing knowledge, various levels of managers and executives, and new B.S. graduates." 165/

In 1978, the BLS reports that there were 182,000 job openings for systems analysts, 247,000 for programmers, 393,000 for computer operators, and 63,000 for computer service technicians. 166/

C. FOREIGN NATIONAL GRADUATES IN SCIENCE AND ENGINEERING FIELDS IN THE UNITED STATES

There has been a particularly noticeable increase in recent years in foreign science and engineering graduate students in the United States. Petroleum engineering seems to be the area in which the most remarkable growth

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163/ Scientific, Engineering, Technical Manpower Comments, v. 18, no. 2, Mar. 1981. p. 5.

164/ Ibid., v. 19, no. 1, Jan./Feb. 1982, p. 3.

165/ Ibid., v. 18, no. 7, Sept. 1981, p. 3.

166/ Ibid., v. 18, no. 2, Mar. 1981, p. 5.

has occurred. If such trends continue throughout the 1980s, a recent NSF report has stated, almost all petroleum engineering graduate students will be non-U.S. citizens, and non-U.S. citizens will comprise over 50 percent of graduate students enrolled in most science and engineering fields. 167/ Table 5, below, compares U.S. science and engineering full-time graduate students with full-time foreign graduate students in the United States enrolled in institutions granting doctoral degrees.

TABLE 5. Comparison of U.S. and Foreign Full-time Graduate Students in Doctorate Granting Institutions 168/

Field of Science or Engineering	Fiscal Year 1974 U.S.	Foreign	% Foreign	Fiscal Year 1979 U.S.	Foreign	% Foreign
Petrol. Eng.	98	163	62%	171	250	68%
Elect. Eng.	5,249	2,401	31%	4,549	3,709	45%
Mech. Eng.	2,775	1,438	34%	2,754	2,241	45%
Comp. Sci.	2,957	819	22%	3,685	1,590	30%
Math & Appl. Math	7,082	1,305	16%	5,204	2,066	28%

Source: Academic Science Graduate Enrollment and Support, Fall 1979, p. 48, 64. NSF Document 80-321.

In all fields, again referring to the data in table 5, there have been significant increases in enrollment of full-time foreign graduate students between fiscal years 1974 and 1979. In petroleum engineering, full-time enrollment of non-U.S. citizens increased by 53.3 percent in FY 1979 over FY 1974, compared to a 19.3 percent growth in U.S. citizen graduate enrollment; in electrical engineering, foreigners increased by 54.4 percent, while U.S. citizen enrollment in this field declined by 15.3 percent; in mechanical engineering, full-time graduate

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167/ National Science Foundation. Situation Report--Selected Federal Agencies' R&D Budgets. Report by Dr. M. Kent Wilson, Director OPRM. [By] Syl McNincy, Jr., Executive Assistant for Budget Policy, Washington, June 22, 1981, updated, July 6, 1981. p. 9.

168/ Ibid.

engineering enrollment of foreigners expanded 56 percent, while comparable U.S. citizen graduate enrollment decreased slightly by 0.8 percent; in computer science, graduate foreign enrollments increased 94.1 percent, U.S. citizen graduate enrollment in this field increased by 25 percent; and in mathematics and applied mathematics, non-U.S. citizen graduate school enrollment expanded 58.3 percent, and the full-time graduate enrollment of U.S. citizens in this area declined 36 percent.

A common concern of both U.S. industry and universities seems to be that "there is a dearth of American-born students pursuing advanced degrees in engineering, and in related research and technical fields. The results are a dwindling pool of U.S.-born talent from which [various] companies can draw their R&D staffs and universities can obtain faculty, and a troubling export of know-how to other countries." 169/ The places of U.S.-born students are being filled by non-U.S. citizens in both college and university classrooms, subsequently in faculty positions in academia, and in technicalindustrial occupations. 170/

According to data compiled by the SMC 171/, in fall 1980, a total of 44,335 full-time engineering students were enrolled in all U.S. graduate schools, including those which do not grant doctorates. Out of this number, 16,120 or 36.4 percent were foreign national students. Students enrolled part-time in graduate engineering school totaled 23,250, of which 2,690 or

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169/ Wanted: U.S.-Born Graduate Students. Chemical Week, v. 128, June 24, 1981. p. 44.

170/ Chesser, Thomas M. Foreigners Snap Up the High-Tech Jobs. The New York Times, July 5, 1981. p. 13.

171/ Vetter, Betty, and Eleanor Babco. Professional Women and Minorities: Manpower Data Resources Service. Washington, Scientific Manpower Commission, Feb. 1981. p. 150.

11.6 percent were foreign nationals. The National Research Council reports that in 1980, 46.3 percent of all doctoral degrees awarded in engineering went to non-U.S. citizens (1,149 out of a total 2,479 awarded). 172/ Of those foreign national students, 299 (12.1 percent) hold permanent visas, while 850 (34.3 percent) hold temporary visas. 173/

The NRC also has found that the type of position that most of the non-citizen Ph.D. recipients expected varied between the permanent and temporary visa groups. Of those holding permanent visas with firm employment plans, 45.8 percent were anticipating jobs in industry or business while 41.8 percent indicated commitments to work in the academic environment. 174/ Of the temporary visa holders with definite employment plans, 61.1 percent intended to work in academe.

Paul Morris, Jr., Head of Chemical Process Industries (CPI), who recruits for the Fox-Morris Company of Wilmington, Delaware, has stated that "foreigners who decide to remain in the U.S. are forced by the marketplace to get higher degrees to compete with U.S. citizens for the same jobs. The majority are of a very high caliber, among the best their country has, and graduate in the top fifth of their class." 175/

In the academic area, Yatish T. Shah, professor and chairman of petroleum and chemical engineering at the University of Pittsburgh, has observed that "it is difficult to get top-quality American graduate students. We have to take foreign students to work on research projects at Pitt, and placement afterwards

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172/ National Research Council. Commission on Human Resources. Summary Report 1980: Doctorate Recipients from United States Universities. Washington, National Academy Press, 1981. p. 12.

173/ Ibid.

174/ Ibid., p. 21.

175/ Wanted: U.S.-Born Graduate Students, p. 45.

is a problem. Sixty to 70 percent of Pitt's full-time graduate enrollment in chemical engineering is foreign." 176/

At the Massachusetts Institute of Technology (MIT), Robert C. Seamans, dean of the school of engineering, reports that, out of 345 faculty members, 20 percent are non-U.S. citizens, and this percentage could go even higher. In 1981 "we have an opening for an assistant professor of aeronautical engineering . . . and received 12 applications--none from U.S. citizens." 177/

The practice of using foreign engineers as faculty members raises two problems, according to Dr. Robert A. Frosch, President of the American Association of Engineering Societies (AAES): (1) the question of "whether these engineers are in effect immigrants, and therefore permanent recruits to the U.S. scene, or whether they are merely a temporary force which will go back to their home countries after a while"; and (2) "language problems, in some cases compounded by cultural differences from the students they are teaching." 178/ These latter differences, however, may be overcome, by requiring new foreign faculty members to take "intensive English language training and possibly some cultural orientation, as part of their early faculty work." 179/

The following list is of various industrial firms that have reported the percentage of non-U.S. citizens that they employ:

- -- The Xerox Corporation--15 percent of its 2,000-person domestic staff are resident aliens;

176/ Ibid.

177/ Ibid.

178/ U.S. Congress. House. Committee on Science and Technology. Engineering Manpower Concerns. Hearings, 97th Cong., 1st Sess. Washington, U.S. Govt. Print. Off., 1981. p. 14.

179/ Ibid.

-- General Electric--25 percent of a 350-person research and development staff at its research facility in Schenectady, New York, are non-U.S. citizens;

-- Intel, a manufacturer of computer memory circuits and other electronic components--Non-U.S. citizens account for 40 percent, out of 500 research staff members, also 75 percent of 100 Ph.D.s on the staff; and

-- DuPont--20 percent of about 400 research-oriented Ph.D.s are foreigners. 180/

David Small, president of Scientific Placement, an executive search firm that locates positions for middle- and upper-level technical personnel, has been reported as stating that many corporations make conservative estimates of the number of non-U.S. citizens they employ. "Most don't include the number of aliens that have since gone on to become U.S. citizens. If you want to count them, you can add another 5 to 10 percent to their total." 181/

According to a report by the American Electronics Association, about one-third to one-half of all foreign national graduates in technical areas return to their native lands. 182/ The study points out, however, that there are benefits to having these foreign students in the United States. 183/ They are:

-- [P]ayment of badly needed non-resident tuition dollars to universities and colleges;

180/ Chesser, Thomas M. Foreigners Snap Up the High-Tech Jobs, p. F 13.

181/ Ibid.

182/ American Electronics Association. Technical Employment Projections of Professionals and Paraprofessionals, 1981-1983-1985. Palo Alto, Calif., American Electronics Association, 1981. p. 184.

183/ Ibid., p. 183-184.

-- [I]ndirect assistance to help third world countries develop as graduates return home; and

-- [G]raduates who do return to their native countries . . . remain sensitive to Western ideology and U.S. products within the international marketplace.

On the other hand, the report also lists some disadvantages:

-- [I]n some cases U.S. students with adequate grade-point records are being excluded for college entrance in favor of foreign students with high records;

-- [N]on-resident aliens--like residents--are putting a strain on academic resources of faculty, classrooms, and equipment which are already at the capacity and perhaps near-stress level; and

-- . . . [We] have a large number of senior faculty in our colleges today who are at or near retirement age. Who will teach the technical students tomorrow? Foreign students who cannot or do not wish to remain in the United States are lost as either teachers or as employees.

D. The Engineering Manpower Shortage: Real or Imagined?

The previous data and discussions presented by different authorities seem to indicate that there is a significant decrease in the supply of some degreed engineering manpower personnel and also similar decreases of personnel to lesser extents in various scientific fields, in relation to the demand. There has been some question, however, as to whether there is actually a shortage. No consensus exists on the shortage question, the SMC reports, especially concerning a future shortage. 184/

On November 16 and 17, 1981, a "Conference on Engineering Manpower Supply and Demand" was held by the IEEE's United States Activities Board (USAB). An IEEE news release reports that, at the meeting, "IEEE leaders argued that, overall,

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184/ Scientific, Engineering, Technical Manpower Comments, v. 18, no. 10, Dec. 1981. p. 6.

there is a balance in supply and demand of U.S. engineers, though there might be a shortage in some regions or specialties." 185/

Robert A. Barden, Chairman of the IEEE/USAB Career Activities Council, contends that, if there were an engineering shortage across the board, median engineering salaries would increase significantly. Statistics cited by Barden indicate that engineering salaries decreased between 1968 and 1981 "when measured in 1968 dollars." He also pointed to a drop in the ratio of "median experienced salaries" to starting salaries over the 13-year period. Barden suggested that conference participants make a distinction between "spot" manpower shortages and "perceived" national shortages. 186/

Dr. Bruno O. Weinschel, Chairman of the American Association of Engineering Societies (AAES) Engineering Affairs Council, stated that "a nationwide engineering shortage is difficult to establish, but there might be a shortage of blue-collar technicians." In addition, he cautioned that "some figures on the engineering shortage might be misstated because of unjustified or multiple future expectations. 'We have to examine some of those squeaky wheels to see if they really need what they claim.'" He also suggested, however, that the current problem with engineering manpower is quality, not quantity 187/, a very important concept in the context of this report, but one which has not been addressed here in detail because of lack of appropriate data. It will be remembered, however, that there was an apparent decrease in the quality of pre-college science and mathematics aptitude discussed in section II, above.

185/ Institute of Electrical and Electronics Engineers, Inc. IEEE Leaders Challenge Perceived Shortage of Engineers: Presidential Science Adviser Plans Engineering Education 'Manifesto.' News Release, Nov. 30, 1981.

186/ Ibid., p. 3.

187/ Ibid.

Whether or not there are shortages of engineers across the board or just in several diverse engineering disciplines seems not to be the major concern expressed by the witnesses at the October 1981 hearings held by the House Committee on Science and Technology. The belief that there are a number of significant problems that need to be addressed involving the U.S. scientific and technical education, and its impact on the Nation's technological productivity, appeared to be the general concern evident at the two-day hearings.

F. Implications for U.S. Science and Technology

The United States is still widely considered the scientific and technological leader of the world. If solutions are not found for the several scientific and engineering manpower problems that have been previously discussed, however, there is concern that this lead may be in jeopardy. As Dr. Frank Press, President of the National Academy of Sciences (NAS) and formerly science adviser to President Carter, testified at the House Committee on Science and Technology hearings, "there is a widespread belief that our technology today is growing less competitive with other industrial nations and that the scientific and engineering facilities in which we educate and train future generations show an alarming slippage in comparative quality," including the "outmoded equipment" used by university science and engineering departments that "often lags behind the technological facilities employed in the laboratories of our industrial plants." 188/

Dr. Press also expressed concern about whether the Nation's colleges and universities could keep up with the "accelerating advances of modern

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188/ House Committee on Science and Technology. Engineering Manpower Concerns, p. 137.

technology" in such rapidly growing fields as "computer engineering, robotics, electronics, genetic engineering, and the several fields of energy engineering," with the shortage of qualified engineering faculty members and overcrowded undergraduate engineering schools. In addition to this, the previously mentioned decline in pre-college student performance of science and mathematical abilities are "longer-term conditions that could limit our ability to stay in the forefront as the world's technological leader." Dr. Press warned that "an impending crisis awaits us in the next decade as these ill-prepared secondary school students begin to move into society or to the level of college education." 189/

John R. Opel, the president and chief executive officer of the IBM Corporation, seems to agree with Dr. Press's conclusions. He has stated, in a report, that "the United States is slipping in the race to strengthen not its capacity in buildings and machines, vital as they are, but the capabilities of its people: talented, educated, and trained human beings — the ultimate resource in any nation." 190/ Furthermore, he indicates, that this national problem also can be seen in international economic competition. Specifically, he states that, "we risk losing out against tougher, more pragmatic, more adventurous international contenders in the years ahead." 191/ To emphasize this point, he lists several areas in which he feels the Nation has begun slipping -- our imports of Japanese and German automobiles, steel, and television sets (not to mention semiconductor memory chips); our loss of market share in exports of manufactured goods; and above all our rate of increase in manufacturing productivity, which has been lagging behind that of virtually every other industrialized country in the world. 192/

189/ Ibid., p. 144.

190/ Opel, John R. Education, Science, and National Economic Competitiveness. Science, v. 217, Sept. 17, 1982. p. 1116.

191/ Ibid.

192/ Ibid.

Many industrial firms, educators, and several engineering professional societies are attempting to resolve the engineering manpower and science and engineering education concerns discussed above. Examples of such efforts are:

- Eight U.S. corporations, AT&T, DuPont, Exxon, General Electric, General Motors, General Telephone and Electronics, IBM, and Union Carbide, are taking action to help solve the university engineering faculty shortage;

- The Exxon Corporation has announced a $15 million grant to 66 schools to provide living expenses for graduate students and supplemental salaries for engineering faculty;

- The Council for the Understanding of Technology in Human Affairs (CUTHA), a consortium of over 100 colleges and universities, is trying to get liberal arts faculties to understand and teach the importance of technology in today's environment;

- The National Research Council of the National Academy of Sciences, and the National Academy of Engineering, has been involved in extensive study of the engineering manpower problem;

- A National Engineering Action Conference with representatives from academia, industry, professional societies, and the Federal Government convened on April 7, 1982, to discuss solutions regarding the situation;

- The Massachusetts High Technology Council (MHTC) is supporting a proposal for its members to give up to 2 percent of their annual research and development budgets to assist universities in hiring more engineering faculty and in buying computer equipment; and

- The U.S. Semiconductor Industry Association anticipates a $6 million budget for 1982 and a $10 million to $15 million budget in 1983. These funds would be made available to universities for research projects in the semiconductor field and also would be used to help increase the number of technical career-oriented graduate students.

In addition to these endeavors, the IEEE has announced that George Keyworth, the president's science adviser, has committed his office to expedite such efforts through the:

- Development of a "manifesto" signed by key U.S. leaders stating engineering education's problems and possible solutions;

- Creation of model programs for sharing limited engineering and science talent between academia and industry; and

- Consideration of a scheme to allow industries to contribute to a university equipment leasing fund. 193/

General Robert Marsh stated during the hearings of the House Committee on Science and Technology that "if this nation is to retain its position as first and foremost in world technological leadership, [it] must pursue a comprehensive, decisive and far-reaching national educational policy for the coming decade . . . ." 194/ He listed the following recommendations that may assist in accomplishing this task: 195/

> - . . . [A] national goal [should be set] to be first in the world in the scientific and technological fields;
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> - . . . [T]he primary and secondary school curricula [must completely be restructured] to provide an education strong in the scientific and technical areas. This includes upgrading the facilities as well;
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> - . . . [I]ncreased pay and benefits [should be supported] to attract the quantity and quality of teachers needed to ensure a quality education for our students;
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> - . . . [A] long range plan [should be implemented] to increase the capacity of our institutions to turn out quality scientists and engineers in the numbers needed to handle the challenges of the future . . . ;

193/ IEEE Spectrum Announcement, Nov. 6, 1981, p. 1.

194/ House Committee on Science and Technology. Engineering Manpower, p. 50.

195/ Ibid., p. 50-52.

- [P]romote the scientific and engineering education of a vast untapped resource--the minorities and women of the nation;
- . . . [D]evelop and implement a comprehensive program to increase the public's awareness of the challenges, benefits and wonders of science . . . .;
- . . . [P]lace significantly increased funds into research and development for challenging and far-reaching projects to ensure that advances will be there when we need them; and
- For the military-- . . . ensure that we have the ability to attract and retain the quantity and quality of scientists and engineers we need to provide a strong military force . . . .

V. RECAPITUALTION: SCIENTIFIC AND TECHNICAL EDUCATION IN THE UNITED STATES

-- Most elementary school teachers surveyed by the NSF lacked confidence about their knowledge and understanding of science and science concepts;

-- Biology was found to be the most commonly required science course needed for high school graduation in schools across the Nation with such requirements. NSF also found it to be the last science course taken by most high school students, usually in the 10th grade. Consequently, a large number of college students do not receive exposure to science courses beyond 10th grade biology;

-- Seventeen-year-olds showed a continued decline in science achievement in all three assessments taken by the National Assessment of Educational Progress (NAEP) over the periods 1969-70, 1972-73, and 1976-77;

-- The NAEP found, overall, that there was a decline in mathematics achievement among 9-, 13-, and 17-year-olds during the 1970s;

-- Dr. Frank Press has stated that the decline in the scientific and mathematical capabilities of pre-college students are "long-term conditions" that may hinder the Nation's ability to maintain its technological lead;

-- Undergraduate science education has been criticized by the NSF and Department of Education study as being too theoretical and esoteric for most students, and oriented toward those who intend to do graduate study;

-- There have been recent declines in Ph.D. enrollments in the mathematical, physical, and life sciences according to the NSF and Department of Education's study. Because of this trend, there may not be sufficient numbers of qualified individuals to fill anticipated vacant faculty positions in these areas in the mid-1990s when mass faculty retirements are predicted to occur;

-- Graduate engineering school enrollments are declining, especially at the doctoral level. As a result, it has been reported by the Wall Street Journal that the number of engineering doctoral degrees conferred has dropped 25 percent within the last decade;

-- It is not clear whether there is a shortage at the undergraduate level in computer science, but it is clear that there is one on the graduate level according to a Scientific Manpower Commission spokesman;

-- Computer scientists, especially programmers, are in great demand and the supply is inadequate. The demand is about 20 to 40 percent greater than the supply. This situation shows no sign of improving, because the "computer world" is advancing at such a rapid pace, an SMC spokesman has found;

-- In recent years, there has been a noticeable increase in the number of foreign science and engineering graduate students in the Nation, especially in the field of petroleum engineering. If this trend continues throughout the 1980s, predicts the NSF, almost all petroleum engineering graduate students will be non-U.S. citizens, and non-U.S. citizens will comprise over 50 percent of graduate students enrolled in most science and engineering fields; and

-- There is no universal agreement as to whether currently there actually is a shortage of engineers. Leaders of the Institute of Electrical and Electronic Engineers (IEEE) believe that, overall, there is a balance in supply and demand of U.S. engineers, although there may be a shortage in some fields or specialties.

PART II. SCIENTIFIC AND TECHNICAL EDUCATION IN JAPAN, THE SOVIET UNION, AND WEST GERMANY

I. INTRODUCTION

In Japan, the Soviet Union, and West Germany, special emphasis is placed on science, mathematics, and engineering in their educational systems. Leaders in these countries, and perhaps others, apparently believe that scientific and technical literacy plays a significant role in their world positions. Soviet Chairman Leonid Brezhnev, for example, has been quoted as saying that "the field of scientific and technological progress is today one of the major fronts in the historical battle between the two [U.S. and Soviet] systems." 196/ Such a belief may have been the impetus that has led to a work force with extensive scientific and technological literacy and which may become a major threat to the ability of the United States to "generate and incorporate technological change in its production and utilization of goods and services." 197/

The NSF and Department of Education study has found that managerial positions in both the government and industries of the Soviet Union, and particularly of Japan, are staffed by individuals with engineering degrees. Furthermore, it states that "over the past 15 years . . . , while [West] Germany and Japan continued to stress science and mathematics for all their secondary students, and while U.S. secondary students not intending to major in science and engineering were choosing to take fewer science and mathematics courses, the countries' share

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196/ Trimble, Jeff. Russia's New Challenge to U.S.--In the Classroom. U.S. News and World Report, v. 89, July 28, 1980. p. 50.

197/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 59.

of world trade in manufactured items (excluding food and fuel) changed . . . ." 198/ Between 1963 and 1977, "productivity increased in the manufacturing industries of . . . West Germany, Japan, and the U[nited] S[tates] . . . by 114 percent, 197 percent, and 39 percent, respectively." 199/

Part II of this report examines the educational systems of these countries in relation to student instruction in scientific and technological areas. Also, the scientific and technical understanding and capabilities of the general populations are examined. Notable, basic comparisons between the countries and the United States in regard to this instruction are discussed.

198/ Ibid.

199/ Ibid.

II. SCIENTIFIC AND TECHNICAL EDUCATION IN JAPAN

A. ELEMENTARY SCHOOL

The standard Japanese school system is divided into four stages--elementary (6 years); junior high (3 years); senior high (3 years); and higher education (4 years). Kindergartens are placed at the pre-school level for pupils between the ages of 3 and 5 years, and most are private institutions. 200/ Elementary school is entered at the age of 6 and is the first year of a 9-year compulsory education system that ends at the age of 14. 201/ "All students--regardless of achievement, retardation, or attendance records--are automatically promoted each year. . . . [A]fter 6 years in elementary school, all students graduate and are passed on to the junior high school." At the age of 14, the student decides whether or not to continue on to senior high school and eventually pursue a higher education. As of 1972, 90 percent of Japan's 15-year-olds entered senior high school. 202/

The majority of Japanese elementary school teachers are assigned to one class on a particular grade level and teach most subject areas as in the United States. The science and mathematics curriculum per week for each grade consists of

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200/ Statistical Handbook of Japan. Bureau of Statistics, Office of the Prime Minister, Tokyo, 1978. p. 125.

201/ Anderson, Ronald S. Education in Japan: A Century of Modern Development. U.S. Dept. of Health, Education, and Welfare, Office of Education. Washington, U.S. Govt. Print. Off., 1975. p. 111.

202/ Ibid., p. 147.

"7 to 9 hours of social studies, 3 to 6 hours of arithmetic, [and] 2 to 4 hours of science. . . ." 203/ The number of hours per week spent in science and mathematics is significantly higher than in the United States, as discussed in part I, section II, above. Moreover, the Japanese school year is about 240 to 250 days rather than 180 days as in the United States.

1. Mathematics Instruction

Although a national achievement test of 5th and 6th grade students in Japan revealed a decline in writing ability 204/, the learning of arithmetic was found to be very successful. Teachers use the instruction technique of methodical drill along with the new mathematics. It has been reported that mathematics plays an important role in Japan's total culture, and that it is introduced to the child at an early age, beginning with 3 hours per week in the first grade and progressing to 6 hours per week from the 4th through the 6th grades. Arithmetic is believed to be one of the most effectively taught elementary level courses in Japan. 205/ In fact, one author says that "it is commonly understood that those Japanese who attend elementary . . . school in comfortable American suburbs will be a year or two behind their grade level in mathematics . . . when they return to Japan." 206/ Furthermore, "there is a general consensus that more subject matter of greater difficulty should be taught at an earlier age. Therefore, with each curriculum revision the content is constantly being expanded and toughened." 207/

203/ Ibid., p. 112. See appendix 2.

204/ Ibid., p. 117.

205/ Ibid., p. 119, 121.

206/ Vogel, Ezra F. Japan As Number One: Lessons for America. Cambridge, Mass., Harvard University, 1979. p. 160.

207/ Education in Japan, p. 122.

2. Science Instruction

One expert has started that Japan was the first country in the world where elementary-level teachers stressed science as fun and interesting to students, thereby instilling in them a positive attitude toward science. 208/ In spite of this, similar problems have been reported to exist in Japan as in the United States regarding the purposes of science education and the necessity of developing a scientifically literate populace. 209/

Apparently most Japanese elementary school teachers lack the ability and experience to perform correct techniques for scientific experiments and observations necessary for teaching science. 210/ Consequently, in-service training in science is provided for elementary teachers through science education centers. The time spent for training by taking in-service courses can range from a few meetings to one-year programs. Between 1962 and 1974, training was provided for about 2,300 elementary teachers out of a total of 28,000 at the Osaka Prefecture science center, one of several such centers in Japan. 211/ Teachers who receive the in-service training are expected to become "lead teachers" in their schools and assist other teachers with science instruction.

Although most individuals who teach elementary science in Japan usually are not specialists in this area, two, three, and four hours per week are spent

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208/ Mentioned during a telephone conversation on Apr. 14, 1982, by Dr. K. Michael Troost of North Carolina State University, who has extensively studied pre-college science education in Japan.

209/ Thier, Herbert D. In-Service Training of Elementary School Teachers: A United States-Japan Seminar. Science Education, v. 60, Oct./Dec. 1976. p. 556.

210/ Ibid., p. 552.

211/ Ibid.

on science instruction in Japanese elementary schools, which is slightly less than the time spent on mathematics. 212/

B. JUNIOR HIGH SCHOOL

The 3-year junior high or lower secondary school, as it is referred to in Japan, consists of about 4.7 million 12-to-14-year-old youths enrolled in nearly 11,000 schools at this level. Entrance examinations, that are required at most upper level Japanese schools, are not necessary in order to enter junior high schools, except for some "prestigious national and private schools." 213/

The basic course program necessary for most students at this stage is "33 to 34 hours per week, 6 per weekday and 4 on Saturday" of required and elective subjects. During the first 2 years, however, every student must take 30 hours of required subjects and only 4 hours of an elective. An elective is usually a 3- or 4-hour English course which most students take, although it is not required. 214/

Junior high, along with preparing college-bound students, also is designed to allow "job-bound" students the opportunity to explore potential vocations. Such students usually find the chance to do so, during the third junior high school year with 4 extra hours for an elective, aside from the 29 hours of required courses. Actually, "required subjects comprise most of the students' program,

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212/ See appendix 2 for a breakdown of instruction time spent on these subjects.

213/ Education in Japan, p. 125.

214/ Ibid., p. 127.

and there is little choice." Compared with the U.S. counterpart, "there are more requirements and fewer electives . . . but the program is somewhat less rigid than it was in prewar Japan when there were no electives at all." 215/

1. Mathematics Instruction

All students in Japan must take mathematics in junior high school. "Everyone enrolls in the first 2 years of classes together, 4 hours a week. In the third year the curriculum is generally divided into two streams: one for the college-bound or academically oriented students, and the other for the noncollege-bound students. The first group has a total of 5 hours per week; the latter takes 3 hours per week." 216/

The International Project for the Evaluation of Education Achievement, a study conducted by the United Nations Educational, Scientific and Cultural Organization (UNESCO), found that 13-year-old Japanese groups of students "ranked highest in mathematical achievement among those of 12 other countries, including the United States, Australia, and several European countries." 217/ Seventy-six percent of the Japanese students scored in the upper half of the scale.

As previously mentioned, entrance examinations are required for all upper level educational institutions in Japan. These examinations, which usually emphasize mathematics, are believed to significantly motivate students to master the subject. In addition, because of pressure from family and peer-groups to pass the examinations, mathematics is considered to be a "very important subject

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215/ Ibid., p. 128.

216/ Ibid., p. 130.

217/ Ibid.

in terms of social needs and career fulfillment." 218/ Credit for the Japanese success in mathematics also is given to high teaching standards in the elementary grades. 219/

Ezra F. Vogel found during his research that many times during elementary and secondary school years, over half of all Japanese students attend "supplementary schools (juku)" which are basically designed to improve students' chances of passing subsequent entrance examinations to a more desirable high school or college. "Entrance examinations," he states, "to high schools or universities can be so competitive as to cause students to restrict their intellectual breadth, eliminate extracurricular activities, neglect their social development, and, in case of failure, become psychologically depressed." This problem, he concludes, "shows deep failures in Japanese education." 220/

Japanese students study mathematics at a more rapid pace than their U.S. counterparts. Geometry is taught in the 7th, 8th, and 9th grades, instead of in the 10th grade as is usually the practice in the United States. Also, "trigonometric identities" are studied in the 9th grade rather than in the 11th grade as in the United States; and calculus generally is completed by college-bound Japanese students in senior high school. 221/

In contrast to this seemingly impressive course structure, there has been concern among some Japanese mathematicians regarding the little time that teachers spend on "lengthy explanations and theory." The teacher who is considered to be "good" tries to prepare students for entrance examinations

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218/ Ibid., p. 130.

219/ Ibid.

220/ Vogel, Ezra F. Japan As Number One, p. 162.

221/ Anderson, Ronald S. Education in Japan, p. 130-131.

by giving them information and methods needed to face the examination, thereby, perhaps, sacrificing "free inquiry-centered learning methods." 222/ Michael W. Kirst has observed that "classroom teaching techniques in Japan reveal some weaknesses that the U.S. may be able to avoid. A persistent Japanese teaching strategy is the use of imitation and rote learning--methods considered outmoded by most U.S. educators. . . . Japanese high school students rarely question their teachers' viewpoints and are judged on standardized tests by their memorization of facts and concepts." 223/

Ronald Anderson has discovered that "Japanese mathematics teachers are following closely the movements for modernizing mathematics education in various parts of the world, particularly the new mathematics programs in the United States." Furthermore, the Japan Society of Mathematics Education (JSME) "assigned a curriculum study group to work on experimental programs and textbooks," and had as one of its themes at a JSME meeting, "improving the teaching method so as to increase the children's creativity." 224/ The mathematics curriculum that was under revision during the 1970s was aimed at "greater differentiation of junior high mathematics to allow for the widely different abilities of individual students." 225/

222/ Ibid., p. 131.

223/ Kirst, Michael W. Japanese Education: Its Implications for Economic Competition in the 1980s. Phi Delta Kappan, v. 62, no. 10, June 1981. p. 707.
Teaching by using the method of rote learning is also a technique used in many U.S. schools. This method, therefore, probably is not unique to Japanese schools.

224/ Anderson, Ronald S. Education in Japan, p. 131.

225/ Ibid.

2. Science Instruction

In the 1970s, the Japanese Ministry of Education continued the revision of its science curriculum that began in the 1960s in order to "absorb the industrial and scientific progress of the world and strengthen [its] position in world trade." During the 1960s, science teaching was invigorated. Teachers placed emphasis on experiments and observation during the 4-hour-per-week science courses required in grades seven through nine. Anderson reports, however, that this was not enough time to cover all the subjects adequately. Laboratory work and observations were neglected. Therefore, revisions were made in the 1970s by adding more material to the curriculum, and making instruction more "flexible to meet the individual differences of the students." In this manner, Japan has tried to "keep pace with the rapid progress in science and technology." 226/

The Ministry of Education (Mombusho) is the national authority responsible for all school education in Japan, and forms the nucleus of educational administration. The Mombusho formulates standards for curricula, supports and directly controls certain national schools, such as national universities, junior colleges, and technical colleges, in addition to some vocational high schools and experimental laboratories attached to national universities. It provides financial aid to local boards of education and is responsible for national museums, art galleries, the Japan Academy of Arts, as well as several research institutes.

Science teaching in Japan is considered to be successful by most independent observers. For example, a comparative study was made regarding the "geographic concepts and images of the physical world" of Tokyo ninth graders with their counterparts in Chicago, Illinois. Results showed that most of the Tokyo students,

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226/ Ibid., p. 131-132.

who as a whole made a mean score of 75, could read a topographical map and, in turn, locate Washington, D.C. In contrast, about half of the U.S. students could read a topographical map, and very few could identify Tokyo. 227/ Michael Kirst reports that, ironically, Japan makes extensive use of educational materials that originated in the United States in both its science and mathematics curricula, including new physics, chemistry, and biology materials that were developed by the National Science Foundation. Japanese science teachers are kept up-to-date, unlike the typical case in the United States which, Kirst says, does very little in comparison. 228/

C. SENIOR HIGH SCHOOL

It is not compulsory in Japan for students to attend senior high school. The majority of the Nation's 15-year-olds, however, attend and complete senior high school. 229/ Students have the choice of attending three types of upper secondary schools: 230/

> - Comprehensive High School . . . provides two major choices for students. . . . (1) the general curriculum, which includes a college preparatory course, and a terminal course--the latter being a less demanding course designed for those who intend seeking employment on graduation but have not yet chosen a specific vocation; and (2) the specialized curriculum, offering either vocational or nonvocational courses;
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> - Vocational High Schools are generally considered low-prestige schools that can recruit only youth of lower ability. [T]hey do command greater esteem than the vocational stream of the comprehensive high school . . . For boys without financial resources, the vocational school is a godsend. It is not a dumping ground for lower ability youth, as it is in some instances in the United States. The entrance examinations to some of

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227/ Ibid., p. 132.

228/ Kirst, Michael W. Japanese Education, p. 707.

229/ Anderson, Ronald S. Education in Japan, p. 147.

230/ Ibid., p. 154-156.

> the good industrial schools are as difficult as those for good academic schools . . . . [They are, however, terminal, which is considered a major shortcoming, and a waste of potential scientific and technical talent. Youth graduating from these schools are not eligible to enter the university. Job opportunities for such individuals have been reported as favorable]; and
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> - Technical Colleges (kosen) . . . [T]he first institutions of this type were opened in 1962. . . . They are well equipped with the latest machinery and technical apparatus. Junior high school graduates, especially poor boys, are greatly attracted to these technical colleges because they provide a thorough vocational education. Industry has quickly absorbed the graduates and paid them well. . . . But as with the vocational high schools, they provide an absolutely terminal education.

Part-time programs also are offered to students during the day or evening. A small percentage of senior high school students are enrolled in the part-time program and the proportion has been decreasing in recent years. More students from the working class and rural regions are able to attend full-time upper secondary schools.

Part-time courses often are taught by the same faculty members as teach in the full-time schools. Therefore, the course offerings are nearly equal in quality to the full-time subjects. It has been reported, however, that "many part-time schools imitate the full-time high school, preparing their students for university entrance exams and neglecting the needs of working youth." 231/ Nevertheless, "among the Japanese, the part-time senior high school is widely considered inferior to the full-time day school. The education it provides is terminal for most of its students, but a few do aspire to attending a university or junior college." 232/ Basically, graduates from these schools appear to be discriminated against because "employers often bar [such] graduates from sitting

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231/ Ibid, p. 157.

232/ Ibid.

for the examination to enter their firms." Consequently, these individuals have to accept "lesser jobs in smaller companies." 233/

1. Mathematics Instruction

The basic goals of high school mathematics in Japan, including junior high school, are to "develop more advanced mathematical thinking, better problem-solving ability, increased symbolic thinking, understanding of axiomatic structure, and the ability to use mathematics in science, technology, and other studies." 234/

In order to achieve these objectives, all high school freshmen (10th grade) must take mathematics I, a 6-hour course consisting of algebra and geometry, probability, and fundamental analytic geometry. In 1982, mathematics I requirements are supposed to be reduced to a 4-hour course. 235/ The second year (11th grade), college preparatory students continue with mathematics II-B, composed of "advanced algebra and geometry, including vector mathematics, matrices and determinants, and differentials and integrals," taken 5 hours per week; the third year (12th grade) such students take mathematics III, 3 hours per week, totaling 14 credit hours of "analytic geometry, differentials and their applications, integrals and their applications, plus probability and statistics." 236/ Contrastingly, vocational students must take the freshman 6-hour course, mathematics I, and a 3-hour applied mathematics course, "a practical course as for engineering," in their senior year (12th grade). 237/

233/ Ibid.

234/ Ibid., p. 168.

235/ Outline of Education in Japan. Science and International Affairs Bureau, Ministry of Education, Science and Culture, Japan, 1979. p. 20.

236/ Ibid., p. 167.

237/ Ibid. See appendix 3, table 4.

Since 1973, over 100 senior high schools have offered a special comprehensive science and mathematics track for students who plan to major in mathematics and science at the university. Such students are expected to take, following mathematics I, "a new course in advanced mathematics, combining mathematics II [and III] for more than 12 hours" for over 18 hours of mathematics during senior high school. To complete all of this during the 3-year senior high school period, these students must substitute mathematics and science courses in the hours usually set aside for electives. 238/

2. Science Instruction

For students in the academic track, a total of 15 hours of science is required in physics, chemistry, biology, and earth science. 239/ For vocational students, only two or more of these subjects are necessary. The teaching of science and mathematics in Japan has been reported as geared toward teaching the "upper ability groups." (This is reminiscent of a trend in science education in U.S. secondary schools, noted above in section II.B of part I, which has been criticized as being "elitist" in the United States.) Other students are often bored, frustrated, and left behind. Teachers use the textbook extensively because they cover generally all material in university entrance examinations.

As previously mentioned, Japan's mathematics and science curricula make extensive use of materials developed in the United States, specifically by the NSF. 240/ Materials from one such program, the Physics Science Study

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238/ Ibid., p. 168.

239/ Ibid., p. 164.

240/ Kirst, Michael W. Japanese Education, p. 707.

Committee (PSSC), was imported by the Physics Education Society of Japan which conducted seminars with participating U.S. specialists, and adapted the PSSC laboratory equipment to Japanese needs. 241/ Similar uses have been made of educational materials dealing with chemistry, biology, and geology or earth sciences, to help upgrade Japanese upper secondary level science instruction.

The Japanese Government generously supports science education, according to Anderson. 242/ The Science Education Promotion Law was enacted in 1953 to improve science education in the elementary and secondary schools. Basic science equipment at the senior high school level cost $18,000 per school at the time of the writing of the Anderson report, and additional Government subsidies were expected to ensure more equipment. 243/ Science Education Centers are also financed by the Government, along with assistance for research by professional associations on science education, and numerous scholarships to senior high school and university science students. 244/

D. PRE-UNIVERSITY EDUCATION IN JAPAN, IN GENERAL

Programs in mathematics and science, as discussed above, seem to be quite rigorous in Japan. Japanese youth, according to Anderson, like some of their counterparts in other parts of the world, are "currently suffering from

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241/ Anderson, Ronald S. Education in Japan, p. 165.

242/ Ibid., p. 166.

243/ In the United States, funds for purchasing basic science equipment are provided through the budget of local school districts. Therefore, the amount of funding for such equipment would vary across the Nation. This information was received through a telephone conversation with a spokesman at the National Association of Secondary School Principals on May 14, 1982.

244/ Anderson, Ronald S. Education in Japan, p. 166.

alienation, disillusionment, and boredom." Instead of alleviating some of the strain which such a curriculum would seem to impose on Japanese students, however, the "educational authorities are making it more structured, with tougher content. . . ." To help students cope with these pressures, counseling appears to be indicated, but very few high schools have professional counselors. A survey team for the Organization for Economic Cooperation and Development (OECD) suggested that Japanese students' personalities need to be developed "through a more flexible and less pressured scheme of education, with more free time, more curricular freedom, more diversity in extra-curricular activities, and more cooperation among pupils. The OECD report stated that the school system overemphasized "discipline, competition, and imitation, and [did] not giv[e] sufficient attention to cooperation and creativity." 245/

In December 1976, the Japanese Curriculum Council made recommendations to the Minister of Education for improving the curricula in all educational school levels prior to higher education, "that would help pupils and students fully master the carefully selected educational contents in all the stages of elementary, lower secondary and upper secondary schools, so as to make school life freer and more enjoyable without lowering educational standards." 246/ Accordingly, the Ministry of Education revised the "Course of Study" in elementary and lower secondary schools in July 1977, and in upper secondary schools in August 1978, and made statutory arrangements for implementation. 247/

New textbooks have been compiled in compliance with the changes. Transitions were to be made in elementary schools beginning in 1980 and in lower

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245/ Ibid., p. 178.

246/ Outline of Education in Japan, p. 50.

247/ Ibid.

secondary schools in 1981. Improvements are scheduled to be made at the upper secondary school level in 1982 following similar changes on the elementary and lower secondary school levels. The improvements are to be based on the following general policies:

- To pay regard to the independent initiative of each school, thus enabling it to build up the school with its own characteristics;
- To aim for the education adapted to individuality and ability of each student;
- To enable students to lead a freer and more enjoyable school life without lowering educational standards; and
- To have students comprehend and appreciate the pleasure of the working life and lay emphasis on moral and physical education. 248/

E. UNIVERSITY-LEVEL SCIENTIFIC AND ENGINEERING INSTRUCTION

1. Higher Education Institutions

There are three types of institutions of higher education in Japan--universities, junior colleges, and technical colleges. 249/

- The university, admitting upper secondary school graduates or those having the similar scholastic ability, is an institution of higher education, where the wide academic knowledge is imparted to students and specialized arts and sciences are profoundly taught and studied. Instituted in the university are the specified types of faculties where 4-year courses are provided as a principle (in the medical and dentistry course, however, 6-year courses are provided);

248/ Ibid., p. 50-51.

249/ Technical colleges, as briefly discussed in section II.C. above, have the goal of assisting junior high school graduates "acquire the vocational ability through profound study of specialized arts and sciences." The period of study extends over 5 years covering industrial-related courses, and 5 and 1/2 years in "mercantile marine-related" subjects.

> - The junior college is an institution . . . aimed mainly at having students . . . study . . . specialized arts and sciences and foster the ability essential to their professional or actual life. Toward this goal, it provides upper secondary school graduates or those having the similar scholastic ability with 2- to 3-years education in various specialized fields. . . . [V]aried types of courses are instituted; and
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> - The technical college . . ., unlike the university and junior college, . . . is aimed at having lower secondary school graduates acquire the vocational ability through profound study of specialized arts and sciences. . . . In technical colleges, such courses are instituted as the machine engineering course, electric engineering course, industrial chemistry course, civil engineering course, and navigation course. 250/

The Japanese have actively promoted the education of scientists and engineers, although the education has been criticized in some quarters for being too theoretical and general. According to Kirst, "in the 1980s, the Japanese educational system is much better equipped than its U.S. counterpart to produce workers with high levels of skill in math, science, and engineering that the economy of the future will require." 251/

Engineering is reported to be more popular than pure science and is the largest subject area within higher education. 252/ This may be one of the reasons that Japan bestows 20 percent of all bachelor's and about 40 percent of all master's degrees to engineers, figures that have been reported as stable for the past 10 years. 253/ In comparison, about 5 percent of all degrees awarded at each degree level in the United States are in engineering. 254/

250/ Outline of Education in Japan, p. 4.

251/ Kirst, Michael W. Japanese Education, p. 707.

252/ Engineering Our Future. Report of the Committee of Inquiry into the Engineering Profession. Sir Montague Finniston, Chairman. London, Her Majesty's Stationery Office, Jan. 1980. p. 209. This study is referred to as the Finniston Report and will be so called in this report.

253/ Naitonal Science Foundation and Dept. of Education. Science and Engineering Education, p. 59.

254/ Ibid.

The "engineering course" in Japan usually lasts 4 years. A general education is provided in the first 2 years. Although such courses as humanities and foreign languages are included, 3 years are permeated with engineering science. The objective of the final 2 years is to increase students' knowledge of one special engineering subject area, so that a specific engineering discipline is studied in some depth. 255/ In the last year, students usually work on a project that is aimed at helping the student apply the acquired knowledge that has been learned. Some criticism, however, attributed to Japanese industry, is that "courses [are] too basic and [do] not provide enough detailed knowledge which [can] be put to use directly [when] the graduate enter[s] industry." 256/ In response, the universities have contended that "they provide graduates with a firm foundation on which they [can] build for maximum flexibility and responsiveness to changing technology in the future." In general, however, employers expect "their graduate recruits to have a sound basic technical knowledge and a certain breadth of perspective; commercial ability, leadership and specialist skills were generally seen as being the responsibility of the employer to develop through training and structured experience." 257/

2. Graduate School

According to the report, Outline of Education in Japan,

> . . . [T]he graduate school may be attached to the university to enable faculty graduates to make further more profound study of the academic theories and their applications. In the graduate school, two-tier courses are instituted, one the master's course (two-year course) and the other the doctor's course (five-year course as a rule, except in the medical and dentistry courses where six-year courses are provided). . . . 258/

255/ Engineering Our Future, p. 210.

256/ Ibid.

257/ Ibid.

258/ Outline of Education in Japan, p. 4.

It has been reported, however, that "Japanese society does not sufficiently reward those who elect to go on for an advanced degree; instead, industry tends to snap up graduates as fast as they win their bachelor's." 259/ This situation is similar to the current one in the United States involving bachelor's engineering degree recipients, as discussed in section III.C of part I of this report. In fact, the advanced degree program in Japan generally parallels the program in the United States. Students are awarded a master's degree after an additional 2 years of study beyond the bachelor's, which includes 30 credit hours and research leading to a thesis. In Japan, however, only the field of specialization is emphasized and little study is done in related areas. 260/ Despite the fact that there seems to be a relatively low number of students in Japan interested in pursuing advanced degrees, "there is keen competition among institutions to establish advanced programs, probably because graduate schools bring status to the university." 261/

In engineering, differences in the numbers of bachelor's degrees compared with total graduate degrees awarded in Japan in 1980 may reflect this situation--73,468 bachelor's degrees, 7,792 total graduate degrees. In spite of the fact that the United States awards more college and university-level degrees than Japan because of its larger population, Japan "graduates more engineers from undergraduate college programs than the U.S." 262/ In 1980, Japan conferred more engineering degrees in absolute numbers than did the United States, a 9.8 percent difference. See table 6 on the following page.

259/ Anderson, Ronald S. Education in Japan, p. 203.

260/ Ibid., p. 202-203.

261/ Ibid., p. 204.

262/ Kirst, Michael W. Japanese Education, p. 707.

TABLE 6. 1980 Engineering Degrees Awarded in the United States and Japan

	Associate Degree	Bach. Degree	Master's Degree	Doctor's Degree	Total	Percent of Total Population
U.S. a/	no equivalent	68,893	16,243	2,507	87,643	0.038
Japan b/	15,012	73,468	7,135	657	96,272	0.082

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a/ Data received from the National Center for Education Statistics.

b/ Data received through a telephone conversation with a spokesman at the American Society of Engineering Education (ASEE) on April 28, 1982. The science attache at the Japanese Embassy stated, during a telephone conversation, that there is no Associate Degree level in Japanese universities. According to a spokesman at the ASEE, the 15,012 figure, listed under "Associate Degree", represents pre-bachelor's degrees or certificates in engineering, as explained in a letter from the Japanese Society of Engineering Education. Various engineering courses are offered to students attending technical colleges in Japan, which are for lower secondary school graduates who want to acquire vocational abilities. This data may represent such graduates. See page 95, for information about the technical colleges.

F. THE SCIENTIFIC COMPETENCE OF THE JAPANESE PEOPLE

The Japanese reading public is considered so sophisticated that it can be assumed that the "typical reader of the three major dailies [in Tokyo] is better informed about international affairs than the typical reader of America's east coast elite dailies." 263/ Also, "news commentators on Japanese national commercial television," he states, "can assume that the audience has sufficient scientific understanding to use various chemical formulas when discussing pollution, nuclear plants, or other scientific questions." 264/

263/ Vogel, Ezra F. Japan As Number One, p. 158.

264/ Ibid.

Some significant differences between the general education in Japan and in the United States which may account for the high scientific competence of the Japanese population are: 265/

- [T]he Japanese attend school about one-third more than Americans, for 240 days a year compared to 180 days a year in America;
- [A]ttendance rates in primary and junior high school are much higher in Japan;
- By the late 1970s over 90 percent of both Japanese girls and boys were completing high school, compared to approximately 80 percent of all American youth;
- Virtually all Japanese who enter a school complete it. In 1975, for example, 97 percent of those entering high school completed it, compared with 79 percent in America;
- [In 1975,] [a]lthough approximately 35 to 40 percent of college-aged youth were attending a university both in the United States and Japan, because of sizable numbers of American drop-outs, Japanese more often complete their training;
- Almost 40 percent of Japanese males in their mid-twenties have completed four-year colleges compared to about 20 percent of Americans (although the American figure rises to about 30 percent by the late twenties);
- Very few Japanese attend graduate school. However, the desire for higher education in Japan is greater than enrollment figures suggest, for university openings are still not adequate to meet the demand. In America virtually any high school graduate can find a college or university to attend, but in Japan there are roughly three openings for four applicants; and
- [A]fter [Japanese] students have completed their schooling, an extraordinarily high number continue taking a variety of correspondence courses and special study programs in their place of work, whether or not they are required to do so by their company. A very high percentage of the Japanese continue to read serious books and to master new bodies of knowledge. [Likewise, a large number of Americans also probably continue to acquire postgraduate knowledge through similar means. The percentage of the total U.S. population who do so, however, is not known.]

265/ Ibid., p. 160-162.

III. SCIENTIFIC AND TECHNICAL EDUCATION IN THE SOVIET UNION

A. GENERAL EDUCATION IN THE SOVIET UNION

In 1966, the Central Committee of the Communist Party of the Soviet Union issued a resolution that responded to the demands of the "scientific and technological revolution" that was underway for a technically prepared labor force with a more extensive educational background and higher level of literacy. To accomplish this goal, the U.S.S.R. Academy of Sciences, and the U.S.S.R. Academy of Pedagogical Sciences, "the highest scientific and educational institutions in the Soviet Union," launched a reform in general education. 266/ Several scholars and educators established objectives to be achieved, redesigned curricula, and wrote textbooks and manuals for students and teachers.

General education in the Soviet Union is "designed to channel students into the work force at an early age with a background in science and mathematics sufficient to permit them to function productively in a changing high-technology economy." 267/ Accordingly, a national form of education was created with official curricula and examination policies. 268/

266/ Wirszup, Izaak. The Soviet Challenge. Educational Leadership, v. 38, Feb. 1981. p. 358.

267/ Ailes, Catherine P., and Francis W. Rushing. The Science Race: Training and Utilization of Scientists and Engineers, U.S. and U.S.S.R. Strategic Studies Center. SRI International. New York, Crane, Russak and Co., Inc., 1982. p. 13.

268/ Ibid.

B. ELEMENTARY AND SECONDARY SCHOOL

Elementary and secondary education are compulsory in the Soviet Union from ages six through 16, and students spend about 240 days per year in school. The structure of the school system consists of the primary or elementary level, grades 1-4; incomplete secondary level, grades 5-8; and general secondary level, grades 9-10. Specialization begins during the post-secondary level in "the specialized secondary school and in the extensive network of vocational-technical schools." 269/

Mathematics and science instruction are emphasized and introduced at early ages and grade levels--mathematics, introduced in grade one; biology, grade five; physics, grade six; and chemistry, grade seven. 270/ When students have reached the end of the eighth grade, they have already acquired "eight years of exposure to mathematics, three years to physics, and two years to chemistry . . . ." Those students continuing on to the two years of general secondary education will maintain the "mathematics/science-oriented program." 271/ Soviet elementary-level teachers of grades one through three are said to have received rigorous training in mathematics ("five years of algebra, ten years of geometry, and calculus.") Teachers of grades four and above have mathematical backgrounds

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269/ Ibid., p. 18.

270/ Ibid.

271/ On Mathematics in the U.S.S.R.: A Conversation With Izaak Wirszup. Educational Leadership, v. 38, Feb. 1981. p. 362.

equal to that acquired through a master's degree program in any U.S. university. 272/

It is very difficult to compare the educational accomplishments of countries as basically different as the United States and the Soviet Union, according to Dr. Wirszup. In spite of this observation, however, he has made the following comparisons:

- In the United States, . . . about 75 percent graduate from high school [after completing a 12-year curriculum];
- [U.S. students have] an average [of] eight or nine years of arithmetic, one year of algebra, one year of geometry (at most), and [a] lack of high school level physics, chemistry, biology, and astronomy. 273/

In contrast, 98 percent of the Soviet school-age population completes secondary school. Upon such completion, totaling ten years of schooling, students have received:

- Three years of arithmetic (grades one-three);
- Two years of arithmetic combined with algebra (grades four-five);
- Five years of algebra (grades six-ten);
- Ten years of geometry (five of intuitive geometry in grades one-five; three of semi-rigorous plane geometry in grades six-eight; two of semi-rigorous solid geometry in grades nine-ten); and
- Two years of calculus (grades nine-ten; in the future calculus may be taught in grade ten only). 274/

272/ Ibid., p. 16.

273/ Ibid., p. 359-360.

274/ Ibid., p. 360.

Additionally, the general Soviet education also includes:

- Five years of physics;
- Four years of chemistry;
- One year of astronomy;
- Five and one half years of biology;
- Five years of geography;
- Three years of mechanical drawing; and
- Ten years of workshop training. 275/

Aside from the achievements of the Soviet education, which exposes all students, not just elite students, to the mathematics and science oriented program, Dr. Wirszup mentions some problems with the Soviet's educational system. It has become overburdened with its mathematics program combined with "demanding science courses." The system has produced overworked students, many teachers with almost impractical hardships, and displeased parents. It has aggravated notable differences between rural and metropolitan cultural levels and educational standards, and also between "the western Soviet Union and the eastern (Asian) republics, at a time when authorities were priding themselves on narrowing these gaps." 276/

C. POST-SECONDARY EDUCATION

Following the completion of the eighth grade, Soviet students have four options in continuing their educations--(1) "continue general secondary education

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275/ Wirszup, Izaak. The Soviet Challenge, p. 360.

276/ Ibid.

for another two years [ninth and tenth grades] to prepare for the entrance examinations for higher educational institutions"; (2) " . . . enter the specialized secondary institutions which provide the student with the final two years of secondary education plus two to three additional years in specialized post-secondary instruction."; (3) "[enter] vocational-technical education [which focuses] on the training of skilled manpower"; and (4) "students, particularly those whose academic performances has not been up to standards or who for a variety of reasons elect not to pursue the other options (for instance, youth in rural sections of the U.S.S.R.) [can] enter directly into the labor force as unskilled workers." 277/

In the past, general secondary education was usually the route Soviet students sought to enter higher education. Since 1965, however, the number of general secondary education graduates who actually enter higher education institutions has declined from 63.7 percent to 26.2 percent in 1976. 278/ Students, it has been found, have been going either to specialized secondary schools, vocational-technical schools, or waiting for other opportunities to take entrance examinations to higher education institutions while neither in school nor in the labor force. 279/ This latter option has been criticized by Soviet authorities and educational specialists who have "attempted to make alternative educational options attractive." 280/

277/ Ailes, Catherine P., and Francis W. Rushing. The Science Race, p. 22-23.

278/ Ibid., p. 23.

279/ Ibid.

280/ Ibid.

D. SPECIALIZED SECONDARY SCHOOLS

In the Soviet Union, the specialized secondary schools are designed to "prepare the student as a technician in one of a number of specialties which will permit him to be employed within the pertinent sector of the economy." 281/ The specialized secondary school is the primary source of technicians trained to work under the direction of university graduates, usually scientists and engineers, to assist in performing some of the tasks that would be normally done by scientists and engineers. The demand for technically-trained personnel has grown recently because of the increasing technological requirements of the Soviet economy. 282/

Dr. Wirszup reports that "over 1,200,000 students graduate annually from secondary specialized schools for middle-level professionals, over two-thirds in engineering, agriculture, and management." 283/ By supporting specialized secondary schools, the Soviets can be assured of an ample supply of technicians "to fulfill the changing needs of the economy as expediently as possible." 284/

Technical training is provided for both eighth and tenth grade graduates of general secondary schools, in full- and part-time programs. Eighth grade

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281/ Ibid., p. 25.

282/ Ibid., p. 26.

283/ Wirszup, Izaak. The Soviet Challenge, p. 358.

284/ Ailes, Catherine, P., and Francis W. Rushing. The Science Race, p. 27.

graduates enter a four-year program and receive "technical-applied training," while tenth grade graduates receive training in technical skills in a one-and-one-half to two-and-one-half year program. Students may select from a list of over 450 different specialties. In recent years, economics has been the specialty with the largest enrollment and graduation growth rate, while the numbers enrolling and graduating in engineering specialties has remained constant. 285/

Regardless of the specialty, students spend at least three to five months completing "on-site" industrial training, followed by examinations upon their return to school. Subsequently, the student is required to work on a "diploma project," similar to a thesis, for completion of the program, usually done "while working at an industrial enterprise of the type in which the student will be placed upon graduation." After this is accomplished, the student returns once again to the school he or she is attending in order to complete the "diploma project," and defend it before the State Qualifying Commission. 286/

E. UNIVERSITY-LEVEL SCIENTIFIC AND TECHNICAL PREPARATION

A recent study by U.S. researchers has determined that ". . . all higher education programs in the Soviet Union are professionally oriented, involving a degree of specialization even greater than that in the functionally-oriented courses of study in professional schools in the United States." 287/ The term

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285/ Ibid.

286/ Ibid., p. 29.

287/ Ibid., p. 41.

"specialty" indicates a student's field of study that is chosen when applying for admission to a Soviet higher educational institution. Once admitted, students then follow a "rigidly defined program of study preparing them for a professional occupation in that specialty." Out of about 360 specialties offered in Soviet universities, which are combined in 22 specialty groups, over 200 are in engineering-industrial fields. 288/ Also, among the 22 specialty groups is a category called "university specialties" which includes physics, mathematics, biology, and others, along with the social sciences and humanities. These fields are very similar to those taken in the United States. 289/

Soviet higher educational institutions have been criticized as being very narrow in specialized training, and therefore "highly susceptible to obsolescence and [have] for this reason been the subject of frequent controversy among Soviet education specialists." 290/ In July 1979 a decree regarding higher education was issued by the Ministry of Higher and Specialized Secondary Education declaring "the need for more flexible curricula and greater emphasis on general theoretical background in the training of 'broad-spectrum specialists'" who would have a wider range of knowledge. Notwithstanding, higher education in the Soviet Union has remained basically the same since the 1960s. 291/

288/ Ibid.

289/ Ibid., p. 44.

290/ Ibid., p. 43.

291/ Ibid., p. 43. The Soviet Ministry of Higher and Specialized Secondary Education supervises the educational process in the U.S.S.R., which includes curricula, textbooks, teaching procedures, as well as other aspects of secondary and higher education.

There are two types of higher educational organizations in the Soviet Union--universities and institutes. Universities essentially offer programs in the natural and social sciences, but also include others in various fields. Institutes generally emphasize a particular "area of related specialties specifically oriented toward a given sector of the economy, agriculture, or medicine." In addition to these establishments, there is a special instruction program provided for the training of technological engineers called a "factory higher technical education school," where students are taught at large industrial firms. 292/ Training in the institutes is not considered to be as "qualitatively superior" as that received in the universities. The number of university graduates, however, is relatively small in comparison.

Students who successfully complete academic requirements at higher educational schools receive a diploma instead of an academic degree as in the United States. 293/ Researchers have found that "about 80 percent of those admitted to higher educational establishments in the Soviet Union complete their undergraduate education and receive a diploma." Comparatively, only about 55 percent of such students in the United States receive bachelor's degrees. 294/ Academic degrees are awarded in the Soviet Union only to students who have completed postgraduate work beyond the essential studies required in higher educational programs. 295/

292/ Ibid.

293/ Ibid., p. 44.

294/ Ibid., p. 50

295/ Ibid.

The following is a breakdown of the requirements in the basic academic program of higher education necessary in order to receive a diploma in the Soviet Union.

- Academic programs generally contain from 40 to 50 different courses or subjects which the student must complete. These subjects are organized into cycles: socioeconomic, general scientific, and specialized. In the higher educational institutes in the engineering-industrial branch, a general engineering cycle is included in addition to the other three cycles;
- General theoretical disciplines, including mathematics, physics, and chemistry, are covered during the first three to three-and-one-half years of the higher educational program. Following the first phase of higher education, more intensive study directed toward the narrow field of specialization is undertaken . . . During the latter years of the academic program, students are allowed some choice in the selection of courses; and
- During the last half-year of the higher educational program, students prepare for state examinations or for defense of a diploma project . . . before the state examination board. In the technical higher educational institutions, diploma projects are more common than state examinations. 296/

Upon graduation, students are not free to pursue whatever occupations they may desire. After receiving a diploma, "students are assigned to jobs at enterprises or institutes where they are required to work for three years. Some students with particularly good undergraduate records are allowed to take entrance examinations for graduate study after two years of work." Furthermore, "during the first year at the enterprise or institute, new graduates of higher educational institutions undergo a traineeship, or probationary period, in order to gain practical and organizational skills in their specialties." 297/

296/ Ibid., p. 55-56.

297/ Ibid., p. 56.

A comparison of the number of bachelor's degrees awarded in the United States with diplomas conferred in the Soviet Union, by Major field of study from 1960 to 1979, indicates that "for all fields combined, there were almost 30 percent more graduations from undergraduate programs in the United States than in the Soviet Union. Within the science and engineering fields, the United States graduated about twice as many specialists in the physical and life sciences and mathematics as did the Soviet Union . . . . In engineering alone, the Soviet Union graduated almost six times the number of specialists graduated in the United States . . . . Largely because of the great number of engineering graduates, in the science and engineering fields combined, the Soviet Union graduated about twice as many specialists as did the United States (8.6 percent of the 22/23-year-old population as opposed to 4.3 percent.)" 298/

F. GRADUATE STUDY

Advanced degrees in both the United States and the Soviet Union are awarded to individuals who complete educational training beyond higher education. Advanced degrees offered in the Soviet Union are referred to as the Candidate of Science and the Doctor of Science degrees rather than the Master's and the Doctor of Philosophy degrees as is common in the United States.

In the Soviet Union, there is no degree identical to the U.S. Master's degree. The Soviet Candidate of Science degree is awarded to a student upon completion of an "agreed" course of study and after a dissertation has been

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298/ Ibid., p. 65 and appendix 4.

written and defended. At the same time, "there are exceptions . . . to both the course of study and the dissertation requirement. A large number of students earn the degree by passing examinations and writing and defending a dissertation without ever having been enrolled in a formal program of courses, and the degree is occasionally awarded for the accomplishment of outstanding research work to individuals who have neither taken examinations nor defended a dissertation." 299/ Therefore, in comparison with U.S. degrees, the Candidate of Science degree roughly resembles the U.S. doctoral degree, "but at perhaps a slightly lower level of preparation."

The Soviet Doctor of Science degree does not compare with any advanced degree in the United States. It is basically an honorary degree, in which school attendance is not required, that is awarded to "senior research personnel" for outstanding scientific achievement. 300/

G. EXTENT OF THE SCIENTIFIC SKILL OF THE SOVIET POPULATION

The scientific competence of the general Soviet population may not compare favorably with that of the United States. The average number of years of education completed by the general U.S.S.R. population has increased from "5.9 years in 1960 to 8.7 years in 1977, and is projected to rise to 9.9 years by 1985." 301/ In the United States, 15.4 percent of the total population had

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299/ Ibid., p. 71.

300/ Ibid.

301/ Ibid., p. 14. See appendix 5.

completed four or more years of college, compared with 6.7 percent of the total population of the Soviet Union that had attained an equivalent level (i.e., completed about five years of higher education). 302/ "The distribution of the Soviet population at the higher levels of education," however, "is far more heavily skewed toward the scientific and technical fields than is that of the United States, . . . and can be expected to continue into the future." 303/

On the other hand, a magazine correspondent in Moscow has announced that,

> There is little support here [in Moscow] for the contention that content and scope of science and mathematics curricula place the Soviets far ahead of the U.S. in these fields.
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> Western sources agree that at the end of ten years of school a Soviet student probably is further along in math and science than American high school graduates. But perhaps only one in four goes on to a university or institute. One specialist says U.S. high schools over all may be weaker in science and math than the Soviet's, but American universities are unquestionably stronger. 304/

It also has been reported that "education experts in the U.S. agree that the raw figures may present a somewhat misleading picture. They point out that rural schools and those in smaller cities far from the mainstream of Moscow are slow to receive new instructional materials and to adopt innovations. Additionally, "what the Russians have in their country," Thane Gustafson, a Soviet specialist at the Rand Corporation is reported as saying, "isn't far from the one-room schoolhouse of yesteryear." 305/ Notwithstanding, the NSF and

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302/ Ibid., p. 16.

303/ Ibid.

304/ Trimble, Jeff. Russia's New Challenge to U.S., p. 50.

305/ Ibid.

Department of Education's study states that "though the problem areas in the education and employment of Soviet scientists and engineers appear to be many [they report that there is extensive underemployment of the science and engineering workforce in the Soviet Union], their potential capacity to compete internationally should not be underrated. There are many signs that the inefficiencies are being recognized and the Soviets' general acceptance of the legitimacy of science and engineering pursuits provides a context in which quality may well improve very rapidly." 306/

Dr. Wirszup has stated that the Soviet Union has made a large investment in manpower, the general population has achieved significant educational accomplishments, and the country has acquired a superb science and technology manpower pool that will affect extensively its technical, industrial, and military power. 307/

306/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 60.

307/ Trimble, Jeff. Russia's New Challenge to the U.S., p. 50.

IV. SCIENTIFIC AND ENGINEERING EDUCATION IN WEST GERMANY

A. GENERAL EDUCATION IN WEST GERMANY

The Federal Republic of Germany is composed of ten states (Lander) and West Berlin. In the states, compulsory education lasts nine years, between the ages of six and 15 years. In West Berlin, students must attend school for ten years ending at the age of 16. 308/ Students spend about 185 days per year in school. Following compulsory education, students attend vocational school part-time, between six and 12 hours per week, or continue on to secondary school.

The West German school system has been termed as being a "vertical" system in that the lower- and upper-secondary school levels include many kinds of schools that are not "organizationally connected with one another and that relate to each other rarely or in a very limited manner." 309/

Parents and children have to make educational decisions early in life that usually cannot be reversed. A general requirement is that parents and children decide what secondary school the child will attend after only four years of schooling at the elementary level (in Bremen and West Berlin, elementary schools last for six years). Recently, however, the Standing Committee on Ministers of Education and Cultural Affairs, a committee within the Ministry of Education

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308/ von Dohnayni, Klaus. Education and Youth Employment in the Federal Republic of Germany. Berkeley, California, Carnegie Council on Policy Studies in Higher Education, 1978. p. 17.

309/ Ibid., p. 20.

which is the highest educational authority in each state that is responsible for the administration of the school systems, established the Orientierungsstufe or orientation level. Created for grades 5 and 6, it was designed to prepare and guide students in their selection of a school for further secondary education in the general education schools--the Hauptschule, Realschule, and the Gymnasium. 310/ Because of the inclusion of the orientation level, the ability of students to transfer 311/ from one educational track to another has greatly improved, and decisions regarding schooling beyond the elementary level have been extended to the 7th grade.

The orientation level also can be organized as a separate stage of school independent from the others. This arrangement has been effective in Breman since 1977. Under this system, secondary school begins with the 7th grade. 312/

For secondary school, students may choose to attend--(1) the basic school (Hauptschule) which leads only to opportunities at the age of 15 to work as an "unskilled laborer," or by way of an apprenticeship, in a "skilled trade," in "practical vocations." "Certificates" are not given after one finishes basic school and students must seek employment without one. Graduates from basic schools do not generally have access to continuing schools (Realschulen or

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310/ The Educational System in the Federal Republic of Germany. Prepared by the Secretariat of the Standing Conference of Ministers of Education of the States of the Federal Republic of Germany in Cooperation with the Federal Ministry for Education and Science and the Conference of West German University Rectors. New York, College Entrance Examination Board, 1979. p. 1.

311/ See appendix 7.

312/ The Educational System in the Federal Republic of Germany, p. 1.

Gymnasien), but "every tenth graduate attends a full-time vocational school";

(2) Realschule, "a modern secondary or intermediate school," which awards graduates an intermediate degree (mittlere Reife), is a second choice. Graduates have the opportunity of attending an upper technical school (Fachoberschule) or a technical high school (Fachhochschule), that provide chances for a more eminent career, but usually not for an academic career; and

(3) The Gymnasium which usually leads to the "matriculation examination (Abitur)," the university, and then to an academic or professional career. 313/

Students may attend all public educational institutions free of charge. Necessary school supplies are furnished without charge or freely loaned to them. Financial assistance is provided for students beginning with the 11th grade with insufficient funds when such assistance may become necessary under certain conditions in both general and vocational secondary schools and in institutions of higher education. 314/

B. SECONDARY SCIENTIFIC AND TECHNICAL EDUCATION

The general secondary school education in West Germany seems to be so complete that students who specialize in such diverse areas as classics, mathematics, or modern languages may pursue a degree in engineering at the higher educational level, and thus compete with students who have a more technical background. 315/

313/ Ibid., p. 21-22.

314/ Ibid., p. 2-3.

315/ Engineering Our Future, p. 219.

There is a standard curriculum in West German schools that stresses science and mathematics for all students through the tenth grade. Once a student has reached the tenth grade and has maintained adequate grades (B, B+), the student may continue through the upper secondary schools--grades 11 to 13. 316/ Approximately 75 percent of graduates from the upper secondary schools go on to universities. Also, about one-third of these graduates seek degrees in science, engineering, or mathematics. 317/

C. ENGINEERING EDUCATION

Individuals entering the field of engineering in West Germany usually complete the academic program of secondary school and continue into higher education. Some persons, however, who have worked as apprentices in industry may decide to re-enter full-time education through attending special schools and eventually take engineering degree courses. In essence, one can become an engineer in West Germany not only through the academic route, but also by an "employment based route." 318/

Through the academic route, which is the "traditional . . . system," there are two different kinds of engineers that can be produced--the Ing. grad. (Ingenieur Graduierper, or graduated engineer), who studies in a three-to-four

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316/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 59.

317/ Ibid., p. 60.

318/ Engineering Our Future, p. 219.

year program at a Fachhochschule, and the Dipl. Ing. (Diplom Ingenieur, or an engineer with a diploma), who could be referred to as a technician. 319/

The student seeking the Ing. grad. award usually has worked for a period of time in industry after attending a lower secondary school, and then progressed to full-time study in a technical high school (Fachhochschule). In the technical high school, a three- or four-year course program is taken that basically prepares the student to work as a "mainstream engineer." Immediately following graduation, or after a few years' experience, many "graduated engineers" begin immediately to take courses leading toward the Dipl. Ing. award, "although the career prospects and rewards for Ing. Grads. are good enough to keep the majority in this stream." 320/

Students pursuing the Dipl. Ing. basically are required to complete a program that lasts five to six years and sometimes longer at a Technische Universitat or a Technische Hochschule where advanced training in "engineering theory and applications" is acquired. During the first three years of study, which is basically composed of engineering science courses, the student is required to work in industry for at least six months. The next two years emphasize professional engineering practice in particular engineering fields. Instruction relies heavily "upon the close integration between those institutions and industry and on the substantial industrial experience (required by

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319/ Ibid. Also discussed with a spokesman during a telephone conversation on Feb. 12, 1981 in the Office of Science and Technology at the embassy of the Federal Republic of Germany. A technician in West Germany, the spokesman informed CRS, is not equivalent to one in the United States, but is more advanced.

320/ Ibid., p. 220.

law) of engineering professors." 321/ During the final two years, developing aggregate skills is stressed along with the balancing of knowledge and techniques in order "to equip the student for work in any of the process engineering industries either in a specialized capacity or as an all-rounder." 322/

Technical education and training in West Germany is thorough and uses quality staff and equipment. 323/ In recent years, however, this system of educating engineers has experienced considerable changes. Since the middle 1960s, the number of students seeking a higher education has increased from 240,000 to 930,000 in 1979-80. As a result, there has been a decline in students pursuing the Ing. grad. award, and an increase in those seeking the Dipl. Ing. The reason that students have begun to opt for the higher award is "for status reasons and because it is a more secure ticket to the better engineering jobs." Aside from this, many Ing. grads. have not entered employment as junior engineers upon graduation. Instead, a large number have chosen to stay in school and study toward another degree--in economics, or business, for example--or improve their qualifications and meet requirements in order to receive the Dipl. Ing. award. The latter choice has been popular among engineers "entering the public sector where academic qualifications are important in salary and career terms." 324/

As a consequence, this switch in the supply of engineers has caused a shortage of individuals with "practical skills associated with the Ing. Grad."

321/ Ibid.

322/ Ibid.

323/ Ibid.

324/ Ibid., p. 221.

for West German industry. Various proposals are being considered to counteract this situation. "The new planning framework," the Finniston report states, "provides a potentially powerful means of ensuring that engineering education keeps in step with industry's requirements." 325/

The most current data available reveals that, in 1980, a total of 22,400 degrees were awarded in engineering in West Germany. 326/

D. SCIENTIFIC AND TECHNICAL ABILITIES OF WEST GERMANS

The National Science Foundation and Department of Education report has concluded that "the overall picture in [West] Germany is one of a very high level of science and mathematics literacy among college graduates as well as a strong science/mathematics understanding among the general population. This provides them with the basic tools to continue their education (German law guarantees that all people are entitled to a free education to as high a level as they desire) at a latter point in their careers, as many choose to do." 327/

325/ Ibid., p. 222.

326/ Received through a telephone conversation on Apr. 28, 1982 with a spokesman at the American Society of Engineering Education.

327/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 60.

V. RECAPITULATION AND BASIC COMPARISONS: JAPAN, THE SOVIET UNION, AND WEST GERMANY

Japan, the Soviet Union, and West Germany reportedly emphasize science and mathematics in their educational systems and introduce these subjects at earlier ages and grade levels. In fact, it was reported that West Germany provides such a well-rounded secondary education that students specializing in such diverse subjects as modern languages or the classics in high school could pursue an engineering degree at the higher education level. In Japan and the Soviet Union, students maintain a mathematics/science-oriented program from the first grade through the completion of upper secondary education. All students are exposed to this program, not just the elite students.

In comparison, in the United States, "over 56 percent of the [U.S.] school systems require no mathematics course or only one for graduation from the secondary school program. Changing patterns for courses in secondary schools in the United States do seem to reveal, however, more and better mathematics training for *some* students, especially advanced college-bound students; these students generally complete a calculus course and perhaps a course in probability and statistics." Surveyors discovered that, for most students, "the general level of education in the United States seems to provide at least some training in general mathematics, geometry, and algebra (basic and advanced)." 328/ The NSF and Department of Education study concluded, however, "that one-half of all high school graduates take no mathemetics

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328/ Ailes, Catherine P., and Francis W. Rushing. The Science Race, p. 20.

or science beyond the 10th grade and only one-half of the students entering college have had any significant exposure to physical science or advanced mathematics beyond the 10th grade." 329/

The structure of the educational systems of each country discussed are quite different:

-- Japanese teaching methods emphasize the use of imitation and rote learning, which the majority of U.S. educators consider outmoded;

-- Japanese students rarely question their teachers' viewpoints and are judged on standardized tests by their memorization of facts and concepts;

-- Many U.S. educators encourage class discussions, allowing students to present their views, thereby presenting an opportunity for students to increase their creativity;

-- General education in the Soviet Union is designed to direct students toward the work force at an early age;

-- In the United States, in many cases, emphasis in general pre-college education is designed to lead students to pursue and complete higher education before entering the job market;

-- The Soviet Ministry of Higher and Specialized Education has declared a need for a more flexible curricula because Soviet education seems to be very narrow in specialized training. This flexible curricula would place a greater emphasis on training and provide a general academic background, that would allow a wider range of knowledge to be acquired;

-- In general, U.S. higher education institutions have flexible curricula that tend to provide students with general academic backgrounds; and

-- Persons labeled as "engineers" in one country may be referred to as "technicians" in another.

329/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 47.

In spite of these and other differences, some other comparisons can be made with the number of degrees awarded by each country in the engineering field as well as in some scientific areas. 330/

Data (see appendix 9, table 11) show that, for 1976, the United States had the largest number of graduates in all fields of academic study, followed by the Soviet Union, Japan, and West Germany. The Soviet Union, however, had, in total and relative to all graduates, the largest number of graduates in science and engineering, with the United States second in absolute number and last relatively. Japan was third in the number of science and engineering graduates, but second in the number of engineering graduates per se.

Data for 1979, (as shown in table 9, in appendix 8) available only for the United States and the Soviet Union, indicate that the United States continues to surpass the Soviet Union in the total number of graduates for all fields. The Soviet Union, however, continues to graduate more than twice the number in science and engineering than does the United States, and almost five times as many engineering students. In the physical, life science, and mathematics areas, the United States continues to award almost twice as many degrees as does the Soviet Union, but lags behind in the agricultural sciences. The Soviets graduate over two times the number of U.S. graduates in this latter field.

The data in table 10 in appendix 8 also reveal that the Soviet Union has the largest total number of engineering graduates, plus the largest percentage of engineering graduates relative to its total population,

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330/ The data showing the number of engineering graduates in table 11 (column 5) differ slightly from those of table 10 (column 5) for 1976, but are consistent enough for the broad conclusions suggested here.

while Japan ranks second, the United States third, and West Germany fourth, in both categories. 331/

While the general populace of the United States has been characterized as heading "toward virtual scientific and technological illiteracy," 332/ the general populaces of Japan, the Soviet Union, and West Germany are believed to have a strong level of understanding of science and mathematics. "The key question, of course, is whether it matters that a large part of our population is uncomprehending of science and technology," states Daniel S. Greenberg, editor and publisher of the Washington Science and Government Report. "After all," he continues, "it is possible to use modern machinery without having the remotest notion of how it works; the ubiquitous hand-held electronic calculator is a case in point . . . The American political and administrative tradition," he points out, "holds that the non-technical generalist leader can get by with the assistance of highly skilled advisers; also that engineering management can make up for lack of trained skills on the factory floor." 333/

Concern regarding the technical literacy of the U.S. population relates not only to industrial strength, but to military capabilities as well. Dr. Izaak Wirszup has been quoted as warning that "the Soviet Union's tremendous investment in human resources, unprecedented achievements in the education of the general population and immense manpower pool in science

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331/ See appendix 8 and 9a.

332/ U.S. Report Fears Most Americans Will Become Scientific Illiterates. The New York Times, Oct. 23, 1980. p. A22. It should be taken into consideration, however, that there are many U.S. schools with advanced and special science and mathematics education tracks for bright students.

333/ Greenberg, Daniel S. Germany and Japan Outproduces Us--From Classroom On. Chicago Tribune, June 25, 1980. p. 8.

and technology will have an immeasurable impact on that country's scientific, industrial and military strength." 334/

The NSF and Department of Education report concluded that:

> For all of these countries [Japan, the Soviet Union, and West Germany], it is difficult to separate the effects of government policy, market factors, and social pressures. What is clear is that in each case there is a strong national commitment to quality science and mathematics instruction as an essential part of the pre-college educational process. The result is a work force which, at all levels, has a relatively high degree of science and mathematics skill, and this has been a factor in the very rapid expansion of technical industries. 335/

334/ Trimble, Jeff. Russia's New Challenge to U.S., p. 50.

335/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 60.

PART III: POTENTIAL DIRECTIONS FOR SCIENCE AND ENGINEERING MANPOWER

I. FUTURE DEMAND FOR TECHNICAL MANPOWER IN THE UNITED STATES

The United States Bureau of Labor Statistics (BLS) developed two sets of projections of the demand for scientists and engineers at all degree levels in 1990 for the NSF and Department of Education study. These projections are based on assumptions regarding economic conditions and Federal policy goals during the 1980s. The first projection (referred to as the baseline assumption) assumes that there will be a decrease in unemployment to 4.5 percent by 1990 and a yearly "increase in labor productivity to 2.4 percent by 1985-1990 above the current rate." Based on these and other assumptions, the BLS made the following predictions concerning the demand for scientists and engineers in 1990: 336/

-- . . . [T]he employment of scientists and engineers in science and engineering occupations and at all degree levels will grow by about 40 percent between 1978 and 1990;

-- This growth would create about 180,000 new jobs in the mathematical, physical, life and social sciences, about 480,000 new jobs in the computer professions, and 250,000 new engineering jobs during the twelve-year period [1978-1990];

-- . . . [T]he most rapid growth, about 110 percent, is projected for computer professions;

-- Employment of all engineers combined is projected to grow by less than 25 percent, with the most rapid expansion for mining (almost 50 percent) and petroleum engineers (40 percent);

336/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 27.

-- Estimated growth in all other major subfields [in engineering] ranges between 19 and 28 percent; 337/

-- Among the sciences [occupational] growth is put at 40 percent for psychologists, geologists, statisticians, and economists;

-- Occupations with projected slow growth include atmospheric scientists, physicists and astronomers, and mathematicians, all of which are projected at ten percent or less. 338/

The chart below shows BLS 1990 projections for job openings in the computer science field compared with 1978. The BLS predicts that in 1990, there will be 400,000 job openings for systems analysts, 500,000 for programmers, 850,000 for computer operators, and 160,000 for computer service technicians. Compared with the 1978 demand, this is a 119.7 percent increase in demand for systems analysts, 102.4 percent increase for programmers, 116.2 percent increase for computer operators, and a 153.9 percent increase for computer service technicians. 339/

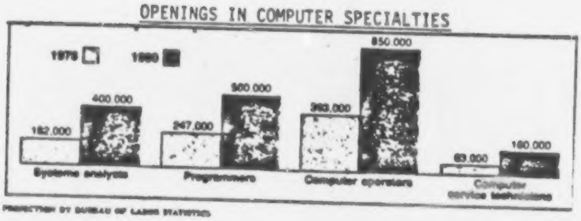
337/ Many computer professionals, the NSF and Department of Education report points out, receive their degrees from electrical engineering departments. Therefore, if demand for this particular group of computer professionals were combined with the demand for electrical engineering, employment in the electrical engineering field probably would grow at a faster rate.

338/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 27.

339/ Scientific, Engineering, Technical Manpower Comments, v. 18, no. 2, Mar. 1981. p. 5. Percentages were computed by CRS from the BLS projection data.

CHART 2. 340/

OPENINGS IN COMPUTER SPECIALTIES



PROJECTION BY BUREAU OF LABOR STATISTICS

The second set of BLS projections were based on three Federal policy goals--(1) "a sharply augmented defense budget"; (2) "large-scale development of synthetic fuels"; and (3) "a balanced Federal budget." The effects that each policy goal would have on the demand for scientists and engineers will be discussed separately below.

(1) A sharply Augmented Defense Budget. Under this assumption, between 1978 and 1990, defense spending, excluding payment of military personnel, would increase by 14 percent or $6 billion in 1972 dollars. Under the assumption that defense expenditures would grow more rapidly and increase by 43 percent, or $18 billion in 1972 dollars, the projected employment of scientists and engineers would only be slightly affected except for aeronautical engineers. Under this condition, the demand for aeronautical engineers, over the twelve-year-period, would increase by about 40 percent; 341/

340/ Ibid.

341/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 27.

(2) Large-Scale Development of Synthetic Fuels. To determine the impact of this assumption on the occupational demand for scientists and engineers in 1990, the BLS consulted with the Department of Energy. Subsequently, it created a theoretical program that called for the "construction and operation of new facilities for coal liquefaction and gasification and oil shale development." This hypothetical program would produce about three quadrillion BTUs. This would be "about three percent of the total energy supply, including imports, projected by BLS to be available in 1990, and equivalent to 1.4 million barrels of oil per day (MMBPD)." Based upon such a synthetic fuels program, the BLS suggests that there would be only a small impact upon science and engineering employment in 1990 that would not change the market assessment made under the first set of projections. 342/ Under the impact of a larger synthetic fuels program, the BLS "assumed that existing technology would be used in production facilities installed over the next ten years." Additional employment, therefore, would be for the building and operating of new plants, requiring only limited numbers of scientists and engineers; 343/ and

(3) A Balanced Federal Budget. With the assumption that the Federal Budget would be balanced by 1983 and continue to be so through 1990, the BLS predicts that this would have "no major effect upon projected 1990 science and engineering employment, since the assumed changes in fiscal policy would affect the economy as a whole and have relatively little

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342/ Ibid., p. 28.

343/ Ibid.

effect on those industries with high concentrations of scientists and engineers." 344/

The demand for science and engineering graduates between 1978 and 1990, the report states, was determined from 1990 employment estimates. This demand would be for "trained but inexperienced workers to replace experienced personnel who would die or retire and to fill the new jobs created in the twelve-year-period." Under both sets of BLS projections of the demand, "about 360,000 scientists and over one million computer professionals and engineers, or a total of about 1.4 million scientists and engineers would be needed to fill growth and replacement demand (excluding openings in academia.") 345/

344/ Ibid.

345/ Ibid.

II. FUTURE SUPPLY OF U.S. TECHNICAL MANPOWER

Projections in the NSF and Department of Education study indicate that, by 1990, the supply of scientists and engineers should be adequate to meet the demand in all fields except the computer professions, statistics, and industrial engineering. 346/ Also, there is a possibility of shortages in some areas of aeronautical engineering if there is a rapid expansion of defense programs. 347/

Table 12 in appendix 10 gives the report's overall projections for the science and engineering market in 1990. The report states that these projections may be optimistic because they are based on the assumption that colleges and universities will have the necessary capabilities to educate all qualified undergraduate and graduate level students who will be seeking various science and engineering degrees. 348/ Skeptics, however, suggest that this assumption may be unfounded, especially for engineering colleges because of "rising undergraduate enrollments, falling levels of Ph.D. production, and faculty shortages [which] indicate that these colleges may not be able to train all qualified applicants." 349/ "In this case," the study concludes, "there would be fewer engineers available in 1990 than the projections indicate, possibly resulting

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346/ Ibid., p. 26.

347/ Ibid.

348/ Ibid., p. 27.

349/ Ibid. The Scientific Manpower Commission has found that the number of Ph.D. degrees awarded in engineering has continuously declined since 1972, and "averages below 200 per year in computer sciences." Scientific, Engineering, Technical Manpower Comments, v. 19, no. 1, Jan./Feb. 1982. p. 1.

in continuing tight markets 350/ in most specialities and, perhaps, serious personnel shortages in a few of them." 351/ The NCES findings corroborate this conclusion. It projects that, by 1985, engineering degrees will increase to 73,400 before declining to about 65,100 in 1990. 352/ The NCES chart below shows that there will be significant decreases in the number of bachelor's engineering degrees awarded in all fields by 1990, except in environmental, mining, and nuclear engineering where the data show no change in degree recipients. 353/ "The decline in 1990 reflects demographic changes," it was reported, with "decreases in the college-age population which is expected to impact at that time." This decline, it is stated further, "should result in degree outcomes that are lower than the 1985 projections for total engineering." 354/ On the other hand, in the area of computer science, NCES data show that bachelor's degrees will probably increase by 58 percent between 1979 and 1987. 355/ "Any increase," notes the Scientific Manpower Commission however, will intensify "a faculty shortage already in evidence,

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350/ "Tight market" indicates that employers might have difficulties in finding qualified individuals to fill existing job openings.

351/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 27.

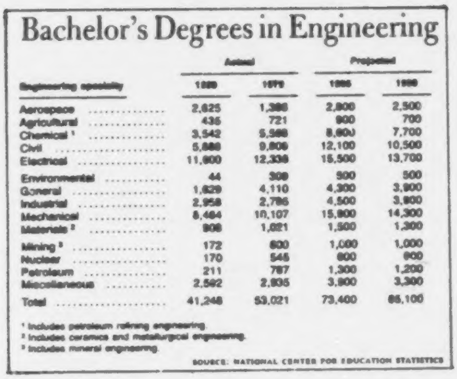
352/ Scientific, Engineering, Technical Manpower Comments, v. 18, no. 3, Apr. 1981. p. 1.

353/ Ibid.

354/ Ibid.

355/ Ibid., v. 18, no. 2, March 1981. p. 5.

CHART 3. 356/



Bachelor's Degrees in Engineering

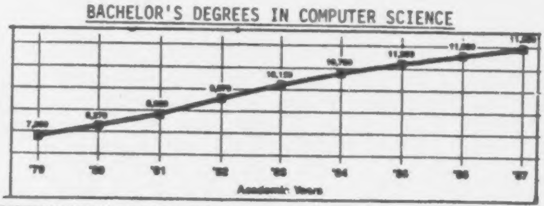
Engineering specialty	Actual		Projected	
	1969	1979	1985	1990
Aerospace	2,625	1,386	2,800	2,500
Agricultural	436	721	900	700
Chemical [1]	3,542	5,568	8,600	7,700
Civil	5,888	9,806	12,100	10,500
Electrical	11,800	12,338	15,500	13,700
Environmental	44	308	500	500
General	1,629	4,110	4,300	3,900
Industrial	2,958	2,786	4,500	3,800
Mechanical	8,464	10,107	15,800	14,300
Materials [2]	908	1,021	1,500	1,300
Mining [3]	172	600	1,000	1,000
Nuclear	170	545	600	900
Petroleum	211	787	1,300	1,200
Miscellaneous	2,592	2,935	3,900	3,300
Total	41,248	53,021	73,400	66,100

[1] Includes petroleum refining engineering.
[2] Includes ceramics and metallurgical engineering.
[3] Includes mineral engineering.

SOURCE: NATIONAL CENTER FOR EDUCATION STATISTICS

at least for the short term." 357/ Chart 5 below shows the projections for bachelor's degrees in computer science.

CHART 4. 358/



PROJECTION BY NATIONAL CENTER FOR EDUCATION STATISTICS

356/ Ibid., v. 18, no. 3, Apr. 1981. p. 1.

357/ Ibid., v. 18, no. 2, March 1981. p. 5.

358/ Ibid.

One of the pitfalls of these projections, appears to be that the BLS, NCES, and NSF do not address, to a large extent, the future supply/demand situation that may exist in various scientific and engineering subfields where future discontinuity between supply and demand is expected. The shortages that may occur in aeronautical engineering if defense programs quickly expand also may be true in other subfields if certain changes, which these projections do not take into account, take place. 359/

359/ Discussed during a telephone conversation with an NSF spokesman on Feb. 22, 1982.

III. REVIEW OF THE POSSIBLE SITUATION

The following table, prepared by the BLS and the National Center for Education Statistics, compares estimates of employment openings by occupation (the BLS contribution) with NCES predictions of the supply of bachelor's and master's degree graduates from 1978 through 1990 in each scientific and engineering field. The NCES projects that, between 1978 and 1990, there will be

TABLE 7. 360/

Comparison of Projected Job Openings with Projected Degrees in Science and Engineering 1978-1990

	Job Openings, 1978–1990 (in thousands) Scenario				*Graduates, 1978–1990 (in thousands) Level*	
	Baseline Assumptions	*Accelerated Defense Spending*	*Synthetic Fuels Program*	*Balanced Federal Budget*	*Baccalaureate Degrees*	*Master's Degrees*
Life and Physical Scientists						
Agricultural	16	16	16	16	193	34
Atmospheric	5	5	5	5	5	4
Biological	38	38	38	37	637	78
Chemical	63	64	64	63	178	26
Geological	22	22	23	22	67	18
Marine	2	2	2	2	10	3
Physics and Astronomy	11	11	11	11	45	19
Total	157	159	157	156	1,135	182
Mathematical Scientists						
Mathematicians	3	3	3	3	102	27
Statisticians	19	19	19	19	3	5
Total	22	22	22	22	105	32
Computer Professionals						
Programmers	300	302	300	299	NA	NA
Systems Analysts	221	223	221	221		
Other	28	29	28	28		
Total	549	553	550	547	110	47
Social Scientists						
Psychologists	76	76	76	75	490	111
Other[1]	100	102	101	99	628	58
Total	176	178	177	175	1,117	170
Engineers						
Aeronautical	34	35	34	24	28	NA
Chemical	22	22	22	21	92	
Civil	95	95	95	94	134	
Electrical	121	128	121	120	172	
Industrial	94	98	94	93	48	
Mechanical	89	95	89	89	171	
Metallurgical	9	9	9	9	16	
Mining	7	7	7	7	11	
Petroleum	11	11	11	11	14	
Other	59	61	59	59	115	
Total	528	561	534[2]	525	929[3]	196
Total all Fields	1,432	1,473	1,439	1,426	3,395	626

[1] Includes economists, political scientists, and sociologists.
[2] Includes 4,000 engineers who are not distributed by field.
[3] Includes 128,000 engineering technology degrees not distributed by field.
NOTE: Estimates of openings do not include academic employment. Detail may not add to totals because of rounding.
SOURCES: National Science Foundation, Bureau of Labor Statistics, and National Center for Education Statistics.

360/ National Science Foundation and Dept. of Education. Science and Engineering Education, p. 29.

about 3.4 million graduates receiving bachelor's degrees in science and engineering, and 630,000 science and engineering master's degree recipients. 361/

The comparisons indicate that there are likely to be large shortages of people with bachelor's and master's degrees in the computer professions and statistics. Large numbers of individuals, however, with mathematical training may be attracted to these fields, the NSF and Department of Education report predicts, thus probably decreasing the projected shortage. 362/ A pitfall in these projections, seems to be that the number of degrees awarded in engineering, especially bachelor's degrees, do not always reflect the number of individuals who actually enter the engineering field as an occupation. This aspect was not considered in the projections. Therefore, there may be fewer numbers of engineering or scientific degreed persons available for employment than the projections indicate. 363/

In engineering fields, as mentioned previously, industrial engineering may have fewer graduates than available job openings; and the fields of aeronautical engineering may experience a small deficit in 1990 if the defense program is accelerated. Nuclear engineering, according to the Department of Energy, may have future shortages, because several universities are eliminating nuclear engineering departments and more are planning to do so. This projection shows disagreement with NCES data 364/ which indicate that there will be no change in the number of nuclear engineering bachelor's degree recipients by 1990.

361/ Ibid., p. 26.

362/ Ibid., p. 28.

363/ Discussed during a telephone conversation with an NSF spokesman on Feb. 22, 1982.

364/ Mentioned on p. 139 of this report.

A study, sponsored by the Department of Agriculture concerning current and future supply and demand in occupations that may require agricultural or natural resources training other than agricultural science, has found that, in 1985, "there may be shortages of workers with training in several job categories such as agricultural engineering and food and agricultural chemistry." 365/ In general, the report concludes that for the overall engineering labor market in 1990, employers may have greater difficulties in locating qualified individuals to fill existing job openings than are indicated by the numbers in the table. 366/

Statistical predictions of overall engineering manpower trends prepared by Lieutenant Colonel Jim Graham of the U.S. Air Force shows that, between 1981 and 1990, there will be 731,000 job openings for 617,000 available engineering graduates, indicating a 114,000 personnel shortage in all engineering disciplines. 367/

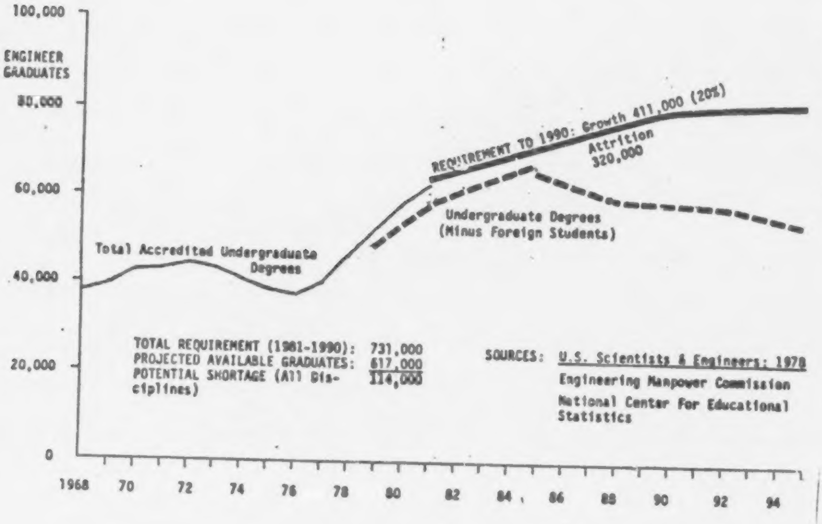
365/ Ibid.

366/ Ibid.

367/ Graham, Jim, LTC. The Engineering Shortage--A National Problem. Long Range Planning. Washington, U.S. Air Force.

CHART 5. 368/

Engineering Manpower Trends/Projections



368/ Ibid.

IV. PREDICTIONS OF THE FUTURE SUPPLY OF SCIENTISTS AND ENGINEERS IN THE SOVIET UNION

Projections of the future supply of scientists and engineers in the three major countries previously discussed were located only for the Soviet Union. Forecasts of the supply of and demand for scientists and engineers in the Soviet Union play a vital role in current and future plans for the Soviet economy. Consequently, an annual plan, five-year plan, and future plans, basically 10-, 15-, or 20-year projections, are designed by Soviet forecasters. 369/ If any differences are found in the estimates of manpower needs and availability, they must be remedied through "training and redirection of manpower flows." Any shortcomings in methods of planning and prediction may affect significantly the operation of the Soviet economy. 370/

A recent U.S. study reported projected graduations in science and engineering in the Soviet Union for the 1980 and 1990 period. 371/ Two estimates were made--high (variant A) and low (variant B)--of the total number of possible diplomas that may be awarded in all fields, in science and engineering generally, in the physical, life sciences and mathematics, in engineering as a separate entity, and in agriculture. Over the period of 1975 and 1979, the rate of the total number of graduates seemed to be stabilizing as compared with high rates of increases in graduates during

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369/ Ailes, Catherine P., and Francis W. Rushing. The Science Race, p. 177.

370/ Ibid.

371/ Ibid., p. 187-190. See table 13, in appendix 11.

the 1960s and early 1970s. Therefore, the rate of graduate growth experienced during the 1975 to 1979 time frame was applied for the 1980 to 1990 projections, which Variant A represents. "Variant B uses the average percentage of the 23-year-old population graduated in each broad field in the 1975 to 1979 period, applied to population projections for 1980 to 1990." Variant A 372/ shows gradual increases in the total number of graduates, under the assumption that "the Soviet leadership will increase the percentage of graduations of the 23-year-old population from the average rate of 16.6 percent in the 1975 to 1979 period to 24.3 percent in 1990, of graduations in the physical and life sciences and mathematics from 1.0 percent to 1.6 percent, and graduations in engineering from 6.4 to 10.0 percent of the 23-year-old population." 373/ Variant B shows a decline in graduations beginning in 1984 which probably "reflects the prospects for the decline in this age group of the population in the Soviet Union in the 1980s." 374/ The actual number of graduates from 1980 and 1990, according to Ailes and Rushing, probably will fall between the two Variant A and B estimates. 375/

Predictions for Candidate and Doctor of Science degrees appear to be more difficult because of the differences in the ways in which the two degrees are

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372/ See table 5, in appendix 4.

373/ Ailes, Catherine P., and Francis W. Rushing. The Science Race, p. 187.

374/ Ibid. See table 13, in appendix 11.

375/ Ibid.

awarded. Projections, however, have been made by the Soviet Defense Intelligence Agency (DIA) for the "benchmark years" 1979, 1985, and 1990. 376/ The Candidate of Science degrees are predicted to remain relatively constant after declining from the 1979 level of 27,800 total degrees in all fields, to 26,300 and 26,400 in 1985 and 1990, respectively. Total Candidate of Science degrees awarded in science and engineering in 1979 were 20,800, and are forecasted to drop to 19,700 in 1985 and remain stationary in 1990. Such degrees conferred in physical, life sciences, and mathematics totaled 7,800 in 1979, and are predicted to decrease to 7,400 in 1985 and 1990, jointly. In 1979, total Candidate of Science degrees awarded in engineering were 11,500, but will probably decline to 10,800 in 1985 and 10,900 in 1990. 377/

Doctor of Science degrees, which normally take an average of about ten years to be awarded, in view of the fact that they are conferred for outstanding scientific achievement, are predicted to increase from the 1979 level in both 1985 and 1990. Subsequently, they are expected to decline. 378/

Ailes and Rushing, however, concluded that these data indicate that "demographic problems [i.e., a decline in the 23-year-old population group in the 1980s] in the Soviet Union may force a reduction in the number of graduates at the higher education and Candidate levels in the 1980s and at the Doctorate level in the 1990s." The techniques used in making the projections, however, "do not account for the possibility that Soviet planners

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376/ See table 14, in appendix 12.

377/ See table 14, in appendix 12.

378/ Ailes, Catherine P., and Francis W. Rushing. The Science Race, p. 189. See table 14, in appendix 12.

may increase the level of enrollment in formal aspirant training in response to demographic constraints and as a result, produce a greater number of Candidates and Doctors of Science than the data would indicate." In addition, "there is a possibility that Soviet planners may increase the percentage enrollment in the science and engineering fields in response to declining overall enrollment patterns." 379/

379/ Ibid.

V. RECAPITULATION: POTENTIAL DIRECTIONS FOR SCIENCE AND ENGINEERING MANPOWER

-- The Bureau of Labor Statistics reports that the employment of U.S. scientists and engineers in science and engineering occupations, and in all such college-degree levels, will increase by 40 percent between 1978 and 1990;

-- About 180,000 new U.S. jobs will be created in the mathematical sciences, physical, life and social sciences, about 480,000 in the computer professions, and 250,000 in engineering between 1978 and 1990, the BLS predicts;

-- The BLS surmises that the most rapid growth in U.S. demand will be for the computer professions, about 100 percent;

-- A total of about 1.4 million U.S. scientists and engineers will be needed in 1990 to fill growth and replacement demand, according to the BLS;

-- By 1985, the number of U.S. engineering degrees awarded will increase to 73,400, before declining to about 65,100 in 1990, the National Center for Education Statistics concludes;

-- The NCES states that there will be significant decreases in the number of engineering U.S. bachelor's degrees awarded in all fields by 1990, except in environmental, mining, and nuclear engineering where the data show no change in the number of degree recipients;

-- The SMC has found that the number of Ph.D. degrees awarded in engineering has continuously declined since 1972, and "averages below 200 per year in computer sciences in the United States";

-- NCES data show that U.S. Bachelor's degrees in computer science probably will increase by 58 percent between 1979 and 1987;

-- Statistical projections of overall engineering manpower trends, prepared by Lt. Col. Jim Graham of the U.S. Air Force, show that between 1981 and 1990, there will be 731,000 job openings for 617,000 available engineering graduates, indicating a 114,000 personnel shortage in all engineering disciplines;

-- Predictions of supply and demand for scientists and engineers in the Soviet Union play an important role in current and future plans for the Soviet economy. As a result, 10-, 15-, and/or 20-year projections of manpower needs are designed. If any discrepancies are detected in manpower needs and availability, they must be remedied through "training and redirection of manpower flows according to SRI International;

-- SRI International researchers state that the Soviet leadership will increase the percentage of graduation in the physical and life sciences and mathematics from 1.0 percent in the 1975 to 1979 period to 1.6 percent in 1990, and engineering graduations from 6.4 percent to 10.0 percent of the 23-year-old population;

-- The Soviet's total Candidate of Science degrees awarded in science and engineering in 1979 were 20,800. This figure is predicted to drop to 19,700 in 1985 and remain stationary in 1990;

-- The Soviet's Candidate of Science degrees conferred in the physical, life sciences, and mathematics totaled 7,800 in 1979, and are projected to decline to 7,400 both in 1985 and 1990;

-- In 1979, total Soviet Candidate of Science degrees awarded in engineering were 11,500, but are anticipated to decline to 10,800 in 1985, and 10,900 in 1990; and

-- Soviet Doctor of Science degrees, which take an average of about ten years to be conferred because they are given for outstanding scientific achievement, are predicted to increase in 1985 and 1990, from the 1979 level.

PART IV: THE SUPPLY OF DEPARTMENT OF DEFENSE SCIENTISTS AND ENGINEERS

I. INTRODUCTION

This report thus far has focused on science and engineering education as it relates to the supply and demand of scientists and engineers in the academic sector, as well as the industrial sector of the United States economy. Certain aspects concerning this issue in Japan, the Soviet Union, and West Germany also have been reviewed.

The supply and demand of scientists and engineers also play a role in the area of defense. Between 25 and 35 percent of the total employed scientists and engineers in the country are supported by defense work. 380/

The demand for engineers in private industry, however, has increased engineer salaries to such a level that the military cannot compete, and therefore is experiencing problems in recruiting new engineering college graduates, as well as, retaining experienced engineers. 381/

An expert has warned that "the growing gap between the scientific training of Americans and their Soviet counterparts . . . poses a grave threat to America's economic and military security." 382/ According to a recent Congressional Research Service (CRS) report,

> It has been a long-standing tenet of U.S. defense policy to counter Soviet military superiority in numbers of men and equipment with technologically superior weapons and supporting systems. U.S. ships, planes, and tanks have become increasingly

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380/ Gansler, Jack. Shortages of Scientists and Engineers. Unpublished statistical report. The Analytic Sciences Corporation (TASC). 19 p.

381/ Katonak, Major Thomas T., USAF. The Engineer Shortage: An Analysis. Executive Summary. Report No. 1365-81, p. iv.

382/ Glockner, David. Wirszup: U.S. Science Education Lagging. The Chicago Maroon, Apr. 7, 1981. p. 1.

> more sophisticated and reliant on high technology . . . [T]here is a general concern, [however,] that whatever edge the U.S. and its allies have enjoyed may be evaporating. 383/

The impact of the perceived shortages of scientists and engineers on the Department of Defense (DOD) has been reported to cause "decreased military preparedness, increased cost of weapons (design), reduced productivity (production), and diminished innovativeness." 384/

In a study analyzing the engineering shortage as it relates to the military, particularly the U.S. Air Force, Major Thomas T. Katonak observes that society has become so complex that research and development (R&D) permeates human existence. The status of nations is estimated by the level of technological achievement and, in essence, scientists and engineers have become national assets. Therefore, it appears that a country "can develop economically and militarily defend itself only to the extent that it can exercise its R&D resources." Furthermore, "the effective use of R&D provides the competitive edge whether the issue is balance of power or balance of trade." The R&D aspects of the Nation's "military-industrial complex," he states, is of utmost interest and importance. In addition, "this complex not only invents, develops and maintains all the weapon systems that make up our military machine but also makes a significant contribution to our gross national product by virtue of the many systems exported to other countries and the vast number of people employed by government contractors and their subcontractors." It is obvious from this explanation of the R&D process, he says, that scientific and engineering manpower

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383/ U.S. Library of Congress. Congressional Research Service. Engineering Manpower: A Survey of the National Problem and the Problem in the Department of Defense. By Paul Zinsmeister. Washington, 1981. p. 2.

384/ Gansler, Jack. Shortages of Engineers and Scientists.

is, relatively, "responsible for the fundamental wellbeing of the United States." Also, "this process functions well only when adequate resources exist." 385/

Because of these and other concerns, the supply of scientists and engineers in the DOD also is discussed in this report.

385/ Katonak, Major Thomas T. The Engineer Shortage.

II. THE EFFECTS OF THE SCIENCE AND ENGINEERING MANPOWER SUPPLY ON THE DEPARTMENT OF DEFENSE

A. MILITARY

The United States Air Force seems to be the branch of the service most concerned with engineering manpower personnel. 386/ "This does not mean that only the Air Force has problems in filling engineer requirements; it probably is more indicative of differences in personnel management concepts and priorities among the services." 387/ In response to a CRS inquiry, the Army reported that it is experiencing shortages in scientific and engineering fields, but the "gravity of the problem is not as acute as the Air Force or the Navy." The Navy, in answering a similar CRS request, did not evaluate its current or possible future engineering personnel. This branch of the service, CRS was told, has been focusing its priorities on "meeting its officers requirements in other specialties." For example, the Navy is involved extensively in solving shortages of nuclear qualified officers. 388/

During the two-day October 1981 hearings of the House Committee on Science and Technology regarding engineering manpower concerns, General Robert T. Marsh, Commander of the Air Force Systems Command (AFSC) at Andrews Air Force Base, stated that, because of higher starting salaries

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386/ U.S. Library of Congress. Congressional Research Service. Engineering Manpower, p. 12.

387/ Ibid., p. 13.

388/ Ibid.

being offered by industry (about $7,000 more) than by the Air Force, industry is outbidding it for technically qualified people. In 1968, he reported, "the Air Force recruited over five percent of the college engineering graduates." Currently, this figure has dropped to about one and a half percent. 389/ General Marsh announced that, since 1976, the Air Force has experienced a continuous decline in engineering personnel. Today, the Air Force is almost 1,100 Military Engineering Officers short of the minimum requirements. 390/ The AFSC, the primary user of engineers in the Air Force, he continued, has a shortage of over 500 military engineers, or ten percent. Shortages are especially critical in the "electrical, astronautical, and aeronautical engineering disciplines" which forms the core of the Air Force engineering manpower staff. 391/

As a result of these shortages, he informed the House committee, the number of experienced military engineers has begun to decline. Within the last three years (since 1978), the AFSC has "suffered a net loss of nearly 7,500 man years" of such experience. "Unlike industry," he reported, the Air Force "cannot hire into middle and top management levels. We must 'grow our own' -- and to date we simply have not been able to replace this experience." 392/ Although the AFSC recently has hired a total of 1,750 new

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389/ House Committee on Science and Technology, Engineering Manpower Concerns, p. 41.

390/ Ibid., p. 44.

391/ Ibid., p. 45.

392/ Ibid.

lieutenants covering all its engineering fields, this has not eliminated the overall shortages in the Air Force.

It has become evident that this shortage of engineers has affected work in "promising technology areas." According to General Marsh, several problem areas are:

> -- In the [AFSC] labs, we started the Aviation Turbine Fuel Technology Advanced Development Program which we hope will develop advanced fuels to reduce our dependence on high cost foreign petroleum. We have had to slow the program down because of lack of people. Ultimately, this slow down will cost us in additional petroleum costs and cause us to continue to rely on foreign supply;
>
> -- [The AFSC has] started technology programs in the space countermeasures arena which require 15 additional technical people--we have only been able to assign one;
>
> -- AFSC has not been able to develop new, non-destructive inspection procedures for detection of fatigue damage in B-52 and A-7D aircraft. This has adversely affected the operational readiness of these aircraft;
>
> -- AFSC attempted to contract out 264 Minuteman Missile circuit boards--no bids were received. The work had to be scheduled in-house, but, because of engineer shortages, the work will take three years versus the originally scheduled two years; and
>
> -- In another instance, AFSC lacked the engineering manpower to promptly identify the need to correct damage left after pylon hole rework. Wings on three aircraft had to be reskinned--at a cost of $600,000. 393/

To help solve the engineering manpower personnel shortage that the Air Force is experiencing, several Air Force scientists and engineers are searching for qualified talent on various university campuses to "try to sell the Air Force as a career." At the present time, there are over 30 different

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393/ Ibid., p. 47.

enterprises being put into operation to "attract, retain, and improve the productivity of engineers in the Air Force . . . ." Some of them are listed below.

-- Increases in ROTC scholarships from 6,500 in FY81 to 7,000 in FY82 with proposed increases of 500 per year through FY85 (pending congressional approval); 394/

-- Increases in the Airman Education Commissioning Program from 309 in 1980 to 450 in 1983. Through this program, airmen with some college education in science and math are sent to college full-time to earn an engineering/scientific degree;

-- The College Senior Engineering Program. This . . . program offers college engineering students the opportunity to enlist in the Air Force at the beginning of their senior year. Students receive full senior airman pay and allowances/benefits while they go to school. Upon graduation, we send them through Officer Training School, commission them, and place in an engineering job. Our FY82 recruiting quota is 150 versus 85 for FY81;

-- The co-op student program which is designed to attract students into our civilian engineering work force. We have approximately 500 people in the program and enjoy an 80 percent retention rate; and

-- Increase in the Air Force Institute of Technology programs, both at the undergraduate level. [In 1981,] 160 newly commissioned officers and 60 from active duty with technical degrees were sent to AFIT for a BS in electrical or aeronautical engineering . . . . On the graduate side, [about] 570 highly qualified officers were sent back to universities to receive advanced engineering and scientific degrees--a 12 percent increase. 395/

394/ According to a spokesman with the AFSC during a telephone conversation on Apr. 12, 1982, Congress has approved the increase in ROTC scholarships. The additional increases through FY 1985, however, are still under discussion.

395/ Ibid., p. 49.

B. CIVILIAN

The Department of Defense has indicated in a report that "the shortage of qualified engineers, skilled technicians, and to some extent scientists with certain expertise--while affecting all sectors--can be particularly critical for Defense." 396/ Starting salaries for many engineers and scientists at DOD are about $4,000 to $6,000 less than those in private industry. Therefore, it has become more difficult to fill entry-level positions. In addition, the quality of the individuals being hired is becoming questionable. 397/

A survey of the seven laboratories in the Army's Electronic Research and Development Command discovered 120 unfilled science and engineering (S&E) positions:

-- 31 S&E positions have been vacant for up to 89 days;

-- 55 S&E positions have been vacant for up to 179 days;

-- 22 S&E positions have been vacant from 180 to 269 days;

-- 6 S&E positions have been vacant from 270 to 359 days; and

-- 7 S&E positions have been vacant for a year or more. 398/

These statistics reflect serious problems being experienced by DOD laboratories in recruiting new personnel and retaining experienced scientist and engineers

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396/ Office of the Under Secretary of Defense. The Status of Scientific and Engineering Personnel in the United States: An Analysis of the Problem, Its Impact on DOD, and the Role of the Defense in the National Arena. White Paper. Washington, 1981. p. 3.

397/ Ibid.

398/ Ibid.

already employed, according to the DOD study. Such problems are believed to stem from "inferior facilities and equipment in the DOD laboratories, [and] a lack of opportunities for growth and advancement." 399/

Several procedures have been implemented that DOD hopes will improve its ability to select and keep science and engineering employees. They include: studies conducted by the military services to review areas of need; "the development of the DOD Science and Engineering Apprenticeship Program for High School students; the initiation of fellowship programs in scarce skill areas; and the NOSC [Naval Ocean Systems Center] and [the Naval Weapons Center in] China Lake experiments designed to retain S&E's by modifying the rigid Civil Service pay and promotion systems." 400/

In addition, DOD has begun to devise a plan that it predicted will combine the various studies by public and private sector groups regarding the perceived national shortage of scientists and engineers, and examine the evidence from the DOD viewpoint; generate fresh data on the situation of science and engineering employees in DOD laboratories; supply "policy-level" support by identifying resources and giving direction in order to assist the attempts by the individual military services to interest and retain science and engineering employees; and devise, examine, and implement innovative ways to solve the problem, and coordinate them with current undertakings. 401/

399/ Ibid., p. 4.

400/ Ibid.

401/ Ibid., p. 5.

III. RECAPITULATION: DOD SCIENTISTS AND ENGINEERS

-- General Robert T. Marsh, Commander of the Air Force Systems Command at Andrews Air Force Base, has reported that, because of industry's higher starting salaries (about $7,000 more), industry is outbidding the Air Force for technically qualified personnel;

-- In 1968, the Air Force recruited over five percent of the engineering graduates. As of October 1981, this figure had dropped to about one and one half percent, Gen. Marsh stated;

-- Since 1976, according to Gen. Marsh, the Air Force has experienced a continuous decline in engineering manpower. At the present time, the Air Force is almost 1,100 Military Engineering Officers short of the minimum requirement;

-- The AFSC, the primary user of engineers in the Air Force, is experiencing a ten percent shortage, over 500 military engineers;

-- AFSC engineer shortages are most critical in the electrical, astronautical, and aeronautical engineering fields which, Gen. Marsh explained, forms the core of the Air Force engineering manpower staff;

-- Since 1978, Gen. Marsh reported, as a result of the engineering manpower shortage, the AFSC has encountered a net loss of almost 7,500 man-years of engineering experience;

-- DOD starting salaries for many engineers and scientists are about $4,000 to $6,000 less than those in private industry; and

-- A survey of the seven laboratories in the Army's Electronic Research and Development Command, discovered 120 unfilled science and engineering positions.

-- The Navy currently is involved extensively in solving shortages of nuclear qualified officers.

PART V. A HISTORY OF CONGRESSIONAL CONCERN AND SOME ACTIONS TAKEN BY THE NATIONAL SCIENCE FOUNDATION RELATED TO SCIENCE AND ENGINEERING EDUCATION

I. HISTORICAL OVERVIEW OF CONGRESSIONAL INTEREST AND SOME NATIONAL SCIENCE FOUNDATION ACTIVITIES IN SCIENCE AND ENGINEERING EDUCATION

A. INTRODUCTION

The Congress and the National Science Foundation together have played an important part in the growth and strengthening of U.S. science and engineering education since the establishment of the NSF in 1950. Because in many cases the Congress directs (through authorization and appropriations bills) programmatic developments which the NSF subsequently carries out, this discussion interweaves congressional and NSF actions as they have occurred over the periods covered, rather than provide summaries of congressional and NSF actions in separate sections.

B. PRE-SPUTNIK ERA (1953-1957)

> The National Science Foundation, in its second annual report to President Truman, warned today of a critical shortage of scientists in the United States that it expected to grow worse in the next few years.
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> . . . [C]ontrasted to that in the Soviet Union, where governmental programs call for a schooling of technical and scientific experts . . . there will be only 15,000 engineering graduates [in the United States] in 1955, [compared] with 50,000 in the Soviet Union, where there had been only 9,000 in 1943.
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> In the engineering field, . . . the shortage tends to feed itself. College seniors "are besieged with personal representatives, so that many students have a choice of jobs upon graduation." Under these circumstances, the foundation concluded, it is too much to expect the requisite number of promising students to turn down

offers of $3,000 to $6,000 a year in favor of spending three or four more years in postgraduate work. 402/

Shortages in scientific and engineering manpower do not appear to be a new occurrence in the United States, as this 1953 excerpt from a New York Times article indicates. Job offers from industry, with high starting salaries to baccalaureate science and engineering graduates also were evident in the early 1950s. In response to this situation, the National Science Foundation which has a mandate to "promote the progress of science", took "no overt steps to attract more students into . . . science and engineering" according to Milton Lomask. Contrary to this statement, however, Lomask points out that "as early as 1954, [Dr. Alan T.] Waterman, [the NSF Director], was opposing the suggested creation of a special manpower commission by the President. [Waterman's] argument was that shortages of scientific and technical workers were 'confined to a few fields, and likely to improve.' Any 'dramatic emphasis' on the problem, he wrote, 'might lead to oversupplies.'" 403/

In a statement before the Senate Appropriations Subcommittee on Independent Offices in April 1953, Dr. Waterman explained that the NSF was providing financial assistance for the training of scientists and engineers, through the awarding of fellowships for graduate scientific training, to help ease the scientific and engineering shortage that the Nation was facing at that time. 404/

402/ Lack of Scientists is Called Critical: 2d Report of U.S. Foundation Says Russia is Outdistancing Us in Engineering Graduates. New York Times, Jan. 17, 1953.

403/ Lomask, Milton. A Minor Miracle: An Informal History of the National Science Foundation. Washington, U.S. Govt. Print. Off., 1976. NSF 76-18. p. 121.

404/ Waterman, Alan T. Statement of Alan T. Waterman, Director, National Science Foundation. Before the Subcommittee on Independent Offices, Senate Appropriations Committee, Apr. 24, 1953. In: Remarks of H. Alexander Smith. Congressional Record, Daily Edition, v. 100, May 5, 1953: 4439.

In fiscal year 1952, NSF awarded its first fellowships to 569 pre-doctoral students and 55 post-doctoral students, out of 2,977 applicants. In fiscal year 1953, 515 pre-doctoral and 42 post-doctoral awards were granted out of 3,298 applicants. 405/

Obligations to NSF for education in the sciences for fiscal year 1954 increased by $480,000 over fiscal year 1953--$1.41 million was allotted in FY 1953 and $1.89 million in FY 1954. 406/

In addition to providing more funding for science education, several Members of Congress expressed their concern regarding the need for additional scientists and engineers, and also the need to make more adequate use of U.S. scientific manpower. Representative George H. Bender, in extensions of remarks in the House in May 1953, stated that "without [the] skills [of scientists], the Nation might find itself in peril. When we realize that this group constitutes only two-tenths of one percent of the population, we recognize that we must be constantly seeking to increase this number." 407/ Senator Alexander Wiley commented in the Senate in August 1954 and on numerous other occasions regarding his concern that the Soviet Union was "far outdistancing us in expanding the reservoir of skilled engineers,

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405/ Ibid.

406/ National Science Foundation. Directorate for Science Education. Science Education Databook. Washington, SE 80-3. p. 19.

407/ Our Reservoir of Scientists: Asset No. 1. Extension of Remarks of George H. Bender. Congressional Record--Appendix, Daily Edition, v. 100, May 15, 1953. p. A2839.

scientists, and other technicians." 408/ Also, he stated that "under these circumstances, for us to fail to provide adequate incentive to talented young scientists; . . . is to be committing, in my judgment, a tragic blunder." 409/

These sentiments appeared to be similar to those of many other Members of Congress as it became more apparent that the Soviet Union rapidly was overtaking the United States in its training of technical manpower. Science magazine reported on the Soviet Union's progress in strengthening its trained professional and scientific manpower between 1940 and 1953, and its plans to graduate 50 percent more engineers from higher educational institutions by 1956. 410/ The Soviets were said to place more emphasis on science and technology training than did the United States and at that time had 400,000 engineers compared with 500,000 in the United States, and 150,000 scientists, compared with 200,000 U.S. scientists. 411/

In addition to the expansion of Soviet technical manpower, there also was apprehension in Congress over the fact that many high school science teachers were being lured away by industry by larger salaries. Several oil companies were offering to double the salaries of high school science teachers. 412/ Senator

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408/ Wiley, Alexander. More Adequate Use of Scientific Manpower. Remarks in the Senate. Congressional Record, Daily Edition, v. 101, Aug. 6, 1954. p. 13505.

409/ Ibid.

410/ DeWitt, Nicholas. Professional and Scientific Personnel in the U.S.S.R Science, v. 120, July 2, 1954. p. 1-4.

411/ Kelly, Harry C. Trends in Supply of Scientists and Engineers in the United States. Science, v. 120, July 2, 1954. p. 5A. The statistics also were noted in remarks made by Rep. Adam Clayton Powell, Jr. who later introduced the National Defense Scientific Education Act in May 1955.

412/ Anderson, Clinton P. Remarks in the House [regarding the study of science at the high school level]. Congressional Record, Daily Edition, v. 101, July 11, 1955. p. 10151.

Clinton P. Anderson observed that "one of the most serious problems now confronting us arises by companies which wish to obtain the services of science teachers, whereas today we need more than ever before in our lives competent science teachers to train the new generations." 413/ He suggested that awarding scholarships to outstanding high school students who did exceptional work in physics, chemistry, and mathematics may be one way that the Nation could catch up with the Soviet Union. 414/

The National Science Foundation apparently anticipated Sputnik. 415/ In 1953, NSF began sponsoring summer institutes for college science teachers to assist them in learning about new developments in their own and related fields. Two summer institutes were held in 1953. The number increased to four in 1954 and, by 1955, 11 were being conducted. In 1956, the number had grown once again to 25 summer institutes. Also in 1956, a new and expanded "science-teacher-training" program was established--"the academic year institute for high school teachers of science and mathematics"--and conducted through two institutes, held in 1957. 416/ Through this plan, high school teachers could take a leave of absence from their jobs and attend a special study program at a university during the regular school

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413/ Ibid.

414/ Ibid. p. 10152.

415/ Lomask, Milton. A Minor Miracle, p. 122.

416/ U.S. Congress. House. Committee on Science and Astronautics. Subcommittee on Science, Research, and Development. The National Science Foundation: A General Review of its First 15 Years. Report prepared by the Science Policy Research Division, Legislative Reference Service, Library of Congress, 89th Cong., 2d Sess., Washington, U.S. Govt. Print. Off., 1966. p. 130-131.

year. 417/ By the 1957-58 school year, the high school academic institutes had grown to 16. In the fiscal year 1957 NSF budget, Congress increased support for the improvement of high school science and mathematics teaching by allotting $5 million dollars more for this purpose than the NSF had requested. 418/

For promising students, during the 1956-57 academic year, the NSF established the Special Projects in Science Education Program which paralleled the Summer Institutes program for teachers. This new program involved three main areas: (1) Curricula studies, which responded to the concern that pre-college instructional programs failed "to arouse motivating interesting and understanding of the scientific disciplines", (2) Student-Participation Projects, that were "planned to increase interest in and understanding of science by students at all educational levels", and (3) Teacher-Training Projects that included "special programs for teachers designed to improve science teaching . . . ." 419/

In November 1956, the NSF initiated the Physical Science Study Committee (PSSC) at the Massachusetts Institute of Technology to present a new way of teaching physics, which included new instructional materials. The PSSC was presented by eight teachers experimentally, to high school students during the 1957-58 school year, and was considered a success. Various pieces of legislation were introduced in Congress for the furtherance of science and engineering

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417/ U.S. Congress. House. The National Science Foundation and Pre-College Science Education, p. 50.

418/ U.S. Congress. House. The National Science Foundation: A General Review, p. 133.

419/ National Science Foundation. Seventh Annual Report, Fiscal Year 1957. Washington, U.S. Govt. Print. Off., 1958. p. 72-76.

education between the 84th Congress and the end of the first session of the 85th Congress, prior to the launching of Sputnik I. Such legislation ranged from a National Defense Scientific Scholarship Act, which authorized the "Commissioner of Education to grant scholarships for study, at the college or graduate level, of subjects in the fields of engineering, physics, chemistry, or similar scientific courses, in order to increase the supply of trained scientific and technical personnel in the United States . . . .", 420/ to a Federal Tuition Loan Guaranty Act, which would provide that "lenders . . . be insured against losses on loans made by them for tuition to science and engineering students after January 1, 1958." 421/ No action however, was taken on any of the legislation.

One set of hearings held within this period was related directly to science and engineering education. The "Shortage of Scientific and Engineering Manpower" hearings were conducted by the Subcommittee on Research and Development of the Joint Committee on Atomic Energy during the 84th Congress, 2nd session on April 17-19, 25-26, and May 1, 1956. This subcommittee appeared "mindful of the mounting threat to this country posed by

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420/ Bates, Dorothy M. Analysis of Legislation Related to Improvement of Scientific Study, Teaching, and Progress in the United States: 79th Cong. to the 85th Cong., 2d Sess, 1945-57. In U.S. Congress. Senate. Committee on Government Operations. Science and Technology Act of 1958. Washington, U.S. Govt. Print. Off., 1958. pp. 152-177. (85th Cong., 2d Sess., Senate. Document No. 90) See Selected Annotated Bibliography, Part V, p. 212.

421/ Ibid.

the Soviet Union," according to Representative Melvin Price, a member of the subcommittee. 422/

The 85th Congress, 1st session was adjourned on August 30, 1957. Sputnik I, the first Russian earth satellite, was launched into space on October 4, 1957.

C. POST-SPUTNIK ERA (1958-1970)

1. The 85th Congress, 2nd Session

With the start of the 2nd session of the 85th Congress on January 7, 1958, "an atmosphere of tension and crisis" was evident as legislators reconvened three months following the launching of the Soviet earth satellite. Dissatisfaction with the state of the Nation's science and engineering education in the schools became more evident. 423/ ". . . [T]he appearance of Sputnik I both confirmed the vigor of Soviet technology and stirred a public demand in this country for more education in the sciences . . . ." 424/ By March 1, 1958, about 90 percent more legislation had been introduced in regard to scientific study, teaching, and general aid to higher education than had

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422/ Price, Melvin Meeting the Need for Scientific Manpower--An Intelligent Approach to the Problem. Remarks in the House. Congressional Record, v. 104, Feb. 3, 1958. p. 1572.

423/ Summarized Legislative History of the 85th Cong., 2d Sess., Report No. 14, Jan. 7, 1959. Washington, American Enterprise Association, Inc., p. 1.

424/ Lomask, Milton. A Minor Miracle, p. 122.

been apparent during the entire first session of the 85th Congress. Ultimately, the 85th Congress initiated a program that granted $900 million for national assistance to education. 425/

President Eisenhower, in his State of the Union address to Congress on January 9, 1958, called for "scientific cooperation with our allies" and urged Congress to pass the necessary legislation to "permit the exchange of appropriate scientific and technical information with friendly countries." He also suggested a "billion-dollar, four-year program to stimulate and improve science education and research." 426/ Consequently, Congress enacted (1) the Euratom Cooperation Agreement (P.L. 85-846) passed August 12, 1958 and signed by the President on August 28, 1958, that authorized cooperation with Belgium, France, West Germany, Italy, the Netherlands, and Luxembourg (which comprised the European Atomic Energy Community) for the "peaceful development of atomic energy;" and (2) the National Defense Education Act of 1958 (P.L. 85-864), approved September 2, 1958, which established "a four-year, $887-million program of student loans, fellowships and other aids to improve our scientific manpower resources" 427/ and which included provisions for science and mathematics instruction, at all educational levels in the United States and the creation of a Science Information Service in the NSF. 428/

425/ Summarized Legislative History, p. 1.

426/ Ibid., p. 4.

427/ Ibid., p. 10, 11.

428/ U.S. Library of Congress. Legislative Reference Service. Legislation Dealing With Science and Technology, 85th Cong., 2d Sess., 1958. Compiled by Dorothy M. Bates, Analyst in American Government and Public Administration, Oct. 15, 1963. p. 1.

Following the launching of Sputnik I, 429/ Congress granted $8.7 million to NSF, stipulating $2.3 million for the teacher-training institutes. By 1958, a total of 126 summer institutes were held--five for college teachers only; three for both high school and college teachers; and 118 for high school teachers only. The Academic Year Institutes conducted had grown to 19. 430/ In addition, there were 85 In-Service institutes which allowed selected secondary science and mathematics teachers with bachelor's degrees to take a personal study program. The program usually stretched over one, two, or three summers, and helped teachers improve their competence in these subject areas and, in many crases, complete work for an advanced degree. 431/

As a result of the success of the Physical Sciences Study Committee project, initiated during the 1957-58 school year, NSF agreed to support a similar project created at Yale University--the School Mathematics Study Group. This program was the product of a new course for grades four through 12 that eventually became known as "the New Math." 432/ One objective of this project was "to provide a sound basis for a solid college course in calculus and analytical geometry by the end of the 12th grade." 433/

429/ On Jan. 31, 1958, Explorer I, the first U.S. satellite was launched.

430/ U.S. Congress. House. The National Science Foundation and Pre-College Science Education, p. 60-61.

431/ National Science Foundation: Eigth Annual Report for the Fiscal Year Ended June 30, 1958. Washington, U.S. Govt. Print. Off., 1959. p. 53-54.

432/ Lomask, Milton. A Minor Miracle, p. 125.

433/ National Science Foundation: Ninth Annual Report for the Fiscal Year Ended June 30, 1959. Washington, U.S. Govt. Print. Off., 1960. p. 82.

These courses were referred to as the NSF Course Content Improvement Program, designed to provide support to secondary and elementary schools in order to improve the content of science and mathematics curricula and courses, and to provide various types of teaching and learning aids to help modernize the Nation's science and mathematics education. 434/ The program eventually included the Chemical Bond Approach Project, a Chemical Education Materials Study (CEMS) project, both presenting new approaches to the study of chemistry; "a resource book on topics in geology by the American Geological Institute, and a group of texts, lantern slides, and films on the atmosphere sciences by the American Meteorological Society"; a Biological Sciences Curriculum Study (BSCS) project, and a social studies project entitled, "Man: A Course of Study" (MACOS). 435/

During the 1958-59 school year, the Summer Science Training Program for Secondary School Students (SSTP) was created as part of the Student-Participation Projects. Through the new program, high-ability "secondary school students [were provided opportunities] to study and work during the summer with experienced scientists and mathematicians at sponsoring [higher education] institutions." 436/

434/ National Science Foundation: Tenth Annual Report for the Fiscal Year Ended June 30, 1960. Washington, U.S. Govt. Print. Off., 1961. p. 100.

435/ Lomask, Milton. A Minor Miracle, p. 126, 127, 257.

436/ National Science Foundation: Ninth Annual Report for the Fiscal Year Ended June 30, 1959. Washington, U.S. Govt. Print. Off., 1960. p. 78.

2. The 86th Congress

Although many strides had been made in improving the instruction of science education in the Nation's school system, a warning by NSF was brought to the attention of the House by Representative Victor L. Anfuso, that:

> We have only made a beginning; the major job is still to be done. As a nation, we appear to forget that we live in a competitive world and shall continue to do so. It seems abundantly clear that we shall rapidly lose in competition, unless we can show more determined and constructive efforts than we have during the past years. 437/

With that quote prefacing Mr. Anfuso's remarks, he introduced legislation for the creation of a Science and Technology Agency. That bill, and others like it, did not receive congressional action during the 86th Congress. Another bill, however, introduced by Mr. Anfuso, to establish a National Medal of Science to be awarded to individuals who make outstanding contributions in the physical, biological, mathematical, or engineering sciences, was signed into Public Law 86-209 on August 25, 1959. 438/

Several hearings were held during the 86th Congress in reference to science and engineering education. The House Committee on Science and Astronautics held hearings on Scientific Manpower and Education to examine the problems facing the Nation, at that time, concerning the improvement of science teaching and the

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437/ Need For an Overall Science and Technology Agency. Extension of Remarks of Victor L. Anfuso. Congressional Record, v. 105, Mar. 24, 1959. p. 5122.

438/ U.S. Congress. Senate. Legislative Record: Digest of Achievements and Status of Presidential Recommendations, 86th Cong., 1st Sess., Jan. 7, 1959, to Sept. 15, 1959. Five-Year Review of the Democratic Controlled 84th, 85th, and 86th Congresses [by the Honorable Lyndon B. Johnson, Senate Majority Leader] Washington, U.S. Govt. Print. Off., 1959. (86th Cong., 1st Sess., Senate. Document No. 63) p. 62.

effectiveness of science education at all educational levels; Scientific Information Dissemination, to study the problem of improving the collection and distribution of scientific information within the Nation and abroad by various U.S. libraries, Federal Government agencies, and private institutions, and to what extent such information is available to U.S. scientists and engineers; Scientific and Technical Personnel (H.R. 7981), which involved the creation of a committee to study the need for, composition of, and most efficient means for obtaining a continuous current record of scientific and technical U.S. personnel; and a bill to establish a National Science Academy under the National Science Foundation. Hearings on the National Science Foundation Comparison of the United States and U.S.S.R. Science Education were held by the House Committee on Appropriations. 439/

In fiscal year 1959, Congress had provided $64.3 million in science and engineering education funding, compared with $20.3 million in fiscal year 1958 to NSF. A new International Science Education program was established in NSF that was:

> . . . designed to foster international cooperation and improve communications among nations with respect to problems of science education and scientific manpower. Appropriate professional groups in the various disciplines were given support for a study and evaluation of science subject matter offered in foreign educational systems, with the objective of improving science curriculums in this country. Distinguished foreign scholars were brought [to the United States] to visit the various institutes sponsored by the Foundation. Advanced students and scientists . . . received Foundation support to permit them to participate in international educational programs. 440/

439/ See the Selected Annotated Bibliography, Part V, p. 199.

440/ U.S. Congress. House. The National Science Foundation: A General Review, p. 135.

For fiscal year 1960, Congress appropriated to NSF $66.8 million for total support of scientific manpower, a 3.8 percent increase over fiscal year 1959. 441/

3. The 87th Congress

In 1961, total undergraduate engineering school enrollment in the United States was 232,000, a 0.9 percent decline from 1960. This was reported to be the smallest decrease in four years. 442/ Engineering graduate enrollment, however, had increased at all levels--master's degree enrollment was 32,800, a 5.1 percent increase over 1960; and doctor's degree enrollment was 7,900, 22.1 percent more than the previous year. 443/

Engineering degrees awarded for the 1960-61 academic year showed a 5.2 percent decline in bachelor's degrees conferred compared with 1959-60, which had 35,900 engineering degrees awarded to recipients; master's and other pre-doctoral engineering degrees had increased 13.6 percent with 8,100 awarded; and 943 doctor's degrees in engineering were conferred, a 20 percent increase over 1960. 444/

441/ National Science Foundation: Tenth Annual Report, p. 169.

442/ Tolliver, Wayne E., Henry H. Armsby, and Leah W. Ramsey. Advance Report on Engineering Enrollment and Degrees: 1961. Washington, U.S. Department of Health, Education, and Welfare. Office of Education. Feb. 1962. OE-54004-61. p. 1.

443/ Ibid.

444/ Ibid.

In conjunction with the increases in graduate engineering enrollment and engineering degrees conferred, Congress legislated to extend, for two years, the provisions of the National Defense Education Act, to "stimulate a nationwide effort to strengthen instruction in science, mathematics, and foreign languages" (P.L. 87-344). 445/ The second session of part two of hearings on "A Bill to Provide for the Establishment Under the National Science Foundation, of a National Science Academy," was held on March 28, and May 25, 1961. Originally introduced as H.R. 4986 in the 86th Congress, 1st session, the bill was reintroduced in the 87th Congress, 1st session as H.R. 1, the National Science Academy Act, for "a National Science center consisting of an academy and research institutes to train selected persons in science or engineering for service as officers or employees of the United States." No further action was taken on this legislation.

In 1961, Congress received criticisms from several constituents concerning the NSF's Course Content Improvement Program. Many parents were convinced that "their children were 'being educated by Federal civil servants.'" 446/ "In a long letter in 1961, the NSF Director Alan Waterman assured Senator Mike Mansfield of Montana that these fears were groundless":

> . . . [NSF] limited its support of new high school courses to their development, production, and testing. Grants were made to bodies of scholars and teachers qualified to study curriculum needs. When a study committee produced acceptable material, NSF

445/ U.S. Library of Congress. Legislative Reference Service. Legislation Dealing With Science and Technology, 87th Cong., 1st Sess., 1961. Compiled by Dorothy M. Bates, Analyst in American Government and Public Administration, Oct. 15, 1963. p. 1.

446/ Lomask, Milton. A Minor Miracle. p. 126.

> allotted funds to cover the preparation of the books for publication and the study group arranged for a number of schools to try out the material . . . items provided with the help of NSF funds, . . . were available to 'all potential users' but the Foundation 'always took the position that it should not promote the use of such materials at the local level.'" 447/

Effective June 8, 1962, Reorganization Plan No. II established the Office of Science and Technology (OST) within the Executive Office of the President. An area of OST's responsibility involved "assuring that good and close relations exist with the Nation's scientific and engineering communities so as to further in every appropriate way their participation in strengthening science and technology in the United States and the free world." 448/

4. The 88th Congress

In 1963, James R. Killian, Jr., former President, and at that time Chairman, of the Corporation of the Massachusetts Institute of Technology (MIT), stated that enrollments in U.S. engineering schools had declined four years in succession. 449/ It was reported in the April 23, 1962 issue of the Wall Street Journal that several U.S. industries, such as the General Electric

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447/ Ibid.

448/ U.S. Congress. Senate. Summary of the Three-Year Kennedy Record and Digest of Major Accomplishments of the 87th Cong. and the 88th Cong., 1st Sess., Jan. 3, 1961, to Dec. 30, 1963. Together With a Statement by the Honorable Mike Mansfield, Senate Majority Leader. Washington, U.S. Govt. Print. Off., 1964. p. 259. (88th Cong., 1st Sess. Senate. Document No. 53)

449/ Killian, James R., Jr. Can Government Maintain Vital Scientific Leadership? A Public Service Report of the National Civil Service League, New York. p. 1.

Corporation, had been recruiting scientists and engineers from other countries. "During the year ending last June 30," the article reports, "a total of 3,795 engineers and scientists entered the U.S. as immigrants, compared with 2,862 during the year ending June 30, 1955." 450/ In addition, Nicholas DeWitt had recently published a book documenting science and engineering education in the Soviet Union which was said to provide evidence that the Soviet Union was outproducing the United States in numbers of engineering graduates. 451/

During the 88th Congress, three bills were introduced that directly related to U.S. science and engineering education--H.R. 1012 and H.R. 1016, The National Science Academy Act, to establish a National Science Center under the NSF consisting of "an academy and research institutes to train selected persons in science or engineering for service as Federal employees"; and H.R. 1981, to establish "a 12-member Commission on the United States Science Academy to make a study with respect to the establishment in or near the District of Columbia of a United States Science Academy under the jurisdiction of the Secretary of Health, Education, and Welfare to offer education and training beyond the baccalaureate level in the fields of the physical sciences, mathematics, and engineering." Referred to the House Committee on Science and Astronautics, no further action was taken on the bills.

450/ MacDougall, A. Kent. Recruiting Abroad: U.S. Concerns Step Up Overseas Search for Scientists, Engineers. Wall Street Journal, Apr. 23, 1962. p. 1.

451/ Walsh, John. Manpower: Activist Administration Finds Congress Hard to Convince on Bigger Investment in People. Science, v. 139, Mar. 1, 1963. p. 817.

5. The 89th Congress

In the 89th Congress, a bill similar to H.R. 1012 and H.R. 1016 was introduced, H.R. 153, for the creation of a National Science Academy, under the NSF, for the training of selected individuals in science and engineering for Federal employment. Also referred to the House Committee on Science and Astronautics, no further action was taken.

Concern about the issue was still evident in floor statements and remarks made by a few Members of Congress. Senator Howard W. Cannon stated, ". . . it is my personal belief--and a belief held by many other people knowledgeable in the field--that our entire scientific effort in the decades ahead might well run aground because of an insufficient supply of trained technical personnel." 452/ Senator James W. Fulbright made remarks in the Senate about an article that had appeared in an issue of the Wall Street Journal questioning whether there was really a shortage of science and engineering manpower. The article, 453/ printed in the Congressional Record, suggested that there may have been a surplus of such manpower at that time, at least in the defense and space industries, because of the practice of "stockpiling" engineers in these industries. There was a current "slump in demand for engineers" and several defense-oriented companies were laying off engineers.

452/ Cannon, Howard W. The Nation's Scientific Manpower Policies. Remarks in the Senate. Congressional Record, v. 109, Feb. 7, 1963. p. 2055.

453/ Malabre, Alfred L., Jr. Uneasy Engineers--Many Seek to Acquire New Skills as Demand Softens, Layoffs Mount--Defense Cutbacks Big Factor; Firms Curb Stockpiling of Engineers to Cut Costs--Rush Back to the Classroom. In Remarks of James W. Fulbright. Congressional Record, Daily Edition, v. 110, Feb. 27, 1964. p. 3808-3810.

In fiscal year 1964, NSF established the graduate traineeship program to provide supplementary support for engineering graduate education. Engineers, it was perceived, were in need of advanced training. Statistics showed that "only one percent of the engineers in the United States [held] the doctoral degree and seven percent [held] . . . master's degrees." In comparison, U.S. scientists were found to have a higher percentage of graduate degree holders--19 percent with doctor's degrees, and 38 percent with master's degrees. 454/

Congress appropriated $102.5 million for science education programs for FY64, $120.4 million for FY65; $124.3 million for FY66; and $123.3 million in FY67, all awarded during the 88th and 89th Congresses.

6. The 90th Congress

Two bills were introduced to establish a National Science Academy (H.R. 1185, H.R. 6894) as in the 88th and 89th Congresses. Referred to the House Committee on Science and Astronautics, no further action was taken.

Several proposals were introduced for a National Institutional Grants Program. One such bill, H.R. 875, proposed by Representative George P. Miller, "set forth the congressional finding that support of scientific research and the education of scientists are essential to the security and welfare of the United States." It authorized "$150 million for fiscal 1967 and each of the four succeeding years for allocation to institutions of higher education."

454/ U.S. Congress. House. The National Science Foundation: A General Review, p. 136.

One-third of the funds would be allocated to such institutions, based on project awards from certain Federal agencies; one-third among the States according to the number of high school graduates, and utilized by the States to assist institutions with well-rated programs in various scientific fields; and one-third to higher education institutions based on the number of advanced degrees conferred. The National Institutional Grants Program would be administered by the Director of the NSF. Referred to the House Committee on Science and Astronautics, two days of hearings were held on June 25, and July 18, 1968. No further action was taken.

7. The 91st Congress

In the 91st Congress, H.R. 35, also introduced by Congressman Miller, called for a National Institutional Grants Program. Hearings were held February 18-27, 1969 by the House Committee on Science and Astronautics. No further action occurred. H.R. 576, the National Science Academy Act, was again reintroduced in the 91st Congress as in the five previous Congresses. Once again, no further action was taken.

In the Senate, Senator Claiborne Pell voiced concern about the future supply of trained scientific and engineering personnel when he stated that, ". . . at the present time our Nation does not have, in the education pipeline, enough engineers to insure that we will possess the needed supply of trained personnel for the years to come." 455/ In the House, Representative John

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455/ Pell, Claiborne. The Expected Shortage of Engineers. Remarks in the Senate. Congressional Record, Daily Edition, v. 113, June 6, 1967. p. 14754.

Brademas placed articles in the Congressional Record from the New York Times and the Washington Post announcing the results of "a 12-nation educational endeavor," sponsored by the International Project for the Evaluation of Education Achievement 456/ which compared student achievement in mathematics. The project found that U.S. schools ranked low in an international comparison of pupil's mathematical achievements. Schools in Japan were said to be doing "the best over-all job" in that field. U.S. students lagged behind Japan and four other European countries in mathematics--England, Sweden, France, and Belgium. 457/ "Although this country fared well," Mr. Brademas observed, "our achievements in this all important field--the basic building block of scientific research and technological innovation--are far from what they might be." 458/

Through the NSF-sponsored teacher-training institutes, the quality of U.S. science instruction had vastly improved, according to the NSF Annual Report of 1969. It noted a critical need, however, for supplementary training of teachers since the NSF-funded Course Content Improvement Program continuously upgraded science and mathematics curricula used throughout the Nation. 459/

NSF received about a 20 percent reduction in its total appropriations for fiscal year 1969. Its education programs, however, received less than a

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456/ See the Selected Annotated Bibliography, p. 199.

457/ United States Ranked Low in Math Teaching. In Remarks of John Brademas. Congressional Record, Daily Edition, v. 113, March 7, 1967. p. 5734-5736.

458/ Ibid., p. 5734.

459/ National Science Foundation. Nineteenth Annual Report for the Fiscal Year Ended June 30, 1969. Washington, U.S. Govt. Print. Off., 1969. p. 81.

10 percent decrease--"graduate education in science was reduced by about 13 percent; undergraduate education in science . . . increased by 27 percent"; and pre-college science education was reduced by 17 percent. 460/

For fiscal year 1970, Congress appropriated a total of $461.2 million for the NSF budget. Out of this total, $120.1 million was allotted for science education programs. In fiscal year 1971, the reduced amount of $98.8 million was allotted for science education. 461/

D. REVIEW OF RECENT CONGRESSIONAL INTEREST (1971-1982)

1. The 92nd Congress

After the successful mission of Apollo 11 when it landed on the moon in July 1969, a large number of scientists and engineers, especially aerospace engineers, lost their jobs. Budget cutbacks were evident in the areas of space, defense, and industry. 462/ The effect of the mass layoffs on student interest in science and engineering education seems to have been significantly reflected in engineering school enrollments. In fall 1968, there were 77,484 full-time freshmen enrolled in engineering schools across the country. In

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460/ U.S. Congress. House. The National Science Foundation and Pre-College Science Education, p. 124.

461/ Ibid., p. 131, and insert of appropriations for science education.

462/ Hartsfield, Jack. Gold Mine of Local Talent Just Sits. In Remarks of James B. Allen. Congressional Record, Daily Edition, v. 116, Aug. 21, 1970. p. 29695.

fall 1969, the number decreased to 74,113, in fall 1970 it dropped to 71,661, in fall 1971 there were 58,566, and by fall 1972, there were 52,100 freshmen enrolled in engineering, a 29.7 percent decline within three years. 463/ Similarly, full-time sophomore engineering enrollment declined 25.3 percent during this period, and a nine percent decrease was evident in full-time engineering junior enrollment. Substantial increases were not evident again, until fall 1974.

Congress gave much attention to the unemployment of scientists and engineers as evidenced by the various legislative proposals introduced in both the 92nd and 93rd Congresses to assist such individuals. Two bills directed toward science education were introduced in the 92nd Congress. These were H.R. 8, and H.R. 746, for a National Institutional Grants Program, by Representatives George P. Miller and Don Fuqua, respectively, to authorize Federal funding, for fiscal year 1972 and succeeding fiscal years, to higher educational institutions for support of academic science instruction in the United States. Both bills were referred to the House Committee on Science and Astronautics. No further action occurred.

2. The 93rd Congress

During the 93rd Congress, Representative Fuqua reintroduced a bill (H.R. 555) for a National Institutional Grants Program, that was again referred to the House Committee on Science and Astronautics. No action occurred.

463/ Engineering Manpower Commission of Engineers Joint Council. Engineering and Technology Enrollments, Fall 1978. Part I, Enrollments By Schools, Enrollments By Curriculum For All Students. New York, Engineers Joint Council, Jan. 1979. p. 9.

Senator William Brock proposed S. 2242, that directed "the Secretary of each military department to establish an engineering and technology academy to train persons in the technical fields necessary to the military department concerned." Sent to the Senate Committee on Armed Services for consideration, no further action was taken.

3. The 94th Congress

During the 94th Congress, particular interest was aroused regarding the social studies curriculum of an NSF pre-college science education program entitled "Man: A Course of Study" (MACOS). 464/ Congressional action was generated through the introduction of legislation, and discussion by the House Committee on Science and Technology (formerly the House Committee on Science and Astronautics) as the issue related to the 1976 NSF authorization report.

MACOS, one of 53 curriculum projects on the pre-college level created and developed by NSF, was a course on human behavior designed for fifth grade students. MACOS dealt with one specific question, "What is human about human beings?", and two additional ones, "How did they get that way?", and "How can they be made more so?" "One of its purposes is to demonstrate

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464/ See Appendix 14 for a evaluation of the MACOS program. Also, the MACOS program is discussed extensively in a committee print prepared by CRS-- U.S. Congress. House. Committee on Science and Technology. Subcommittee on Science, Research, and Technology. The National Science Foundation and Pre-College Science Education: 1950-1975. Washington, U.S. Govt. Print. Off., 1975. p. 194-206.

that the values cherished by one culture are not necessarily regarded in the same light by another." 465/ The course, which required additional training of the teachers involved, consisted of 65 pamphlets and color films that focused on the lifestyle of the Netsilik Indians, a community of primitive hunters in the Canadian Arctic.

Controversy arose, during the House debate concerning the NSF Authorization bill (H.R. 4723) for the fiscal year 1976 budget, over the course content of MACOS and the method by which it was taught. 466/ Two amendments, introduced by Representatives John B. Conlan and Robert E. Bauman, were voted on. Representative Conlan's amendment stipulated that no funds should be authorized for appropriation to the NSF for the implementation or marketing of course or curriculum programs or materials unless approved by the House Committee on Science and Technology and the Senate Committee on Labor and Public Welfare. The amendment failed to pass by 215 to 196. 467/ The Bauman amendment would have allowed legislators to scrutinize all annual NSF grants that had been approved by the Foundation. 468/ The amendment passed the House by 212 to 199, 469/ but failed Senate approval. No further discussion occurred concerning the MACOS controversy at that time.

465/ Lomask, Milton. A Minor Miracle, p. 258.

466/ Authorizing Appropriations to the National Science Foundation. [Debate and vote in the House] Congressional Record, Daily Edition, v. 121, Apr. 9, 1975. p. 9486-9518.

467/ Ibid., p. 9508.

468/ Lomask, Milton, A Minor Miracle, p. 259.

469/ Authorizing Appropriations to the National Science Foundation, p. 9517.

Senator Jesse Helms introduced a bill (S. 2160) similar to the Bauman amendment that would have provided that "no funds authorized to be appropriated to the National Science Foundation shall be available to implement elementary or secondary curriculum programs or materials unless such programs or materials have been approved by Congress." Referred to the Senate Committee on Labor and Public Welfare, no further action occurred.

Other legislation related to science and engineering education introduced during the 94th Congress were H.R. 5202 by Representative Torbert MacDonald and S. 32 by Senator Edward Kennedy, to create a council of advisors on Science and Technology in the Executive Office of the President and to establish a continuing science and engineering education program through the NSF. Referred to the House Committee on Science and Technology and the Senate Committees on Labor and Public Welfare; Commerce; and Aeronautical and Space Sciences, no further action was taken.

4. The 95th Congress

During the 95th Congress, Senator Edward Kennedy introduced S. 32, the Continuing Education in Science and Engineering Act, that would have mandated the NSF to create a program of continuing education for persons with scientific and engineering training who have either been working in their profession for the last three years or have had careers interrupted for the last three years. Sent to the Senate Committee on Labor and Public Welfare for consideration, no further action occurred. Senator Kennedy also introduced S. 2550, authorizing the NSF "to make grants to encourage the education, employment, and training of women in science and technology." Submitted to the Senate Committee on Human Resources, no additional action was taken.

In 1976, the NSF created a Women in Science Program to help attract and retrain women in scientific careers. Three projects were established to implement this program--Science Career Workshops that provided career-information and advice to women undergraduate students or those with at least a bachelor's degree in science and also guidance regarding further education or how to obtain scientific jobs to make full use of their potential; the Science Career Facilitation Project to aid the entry or reentry of women with bachelor's or master's degrees in science into scientific careers or into graduate science education programs; and the Visiting Women Scientists Program, begun in 1977, under which women scientists visited high schools across the Nation to promote interest among young people in possible scientific and technical careers. 470/

5. The 96th Congress

During the 96th Congress, increased concern became evident regarding the underrepresentation of women, minorities, and the handicapped in scientific and engineering fields. Legislation was introduced (S. 568) by Senator Edward Kennedy to create an extensive program to expand the contributions and achievements of women in scientific and technical careers. Under this legislation, the NSF was to make grants to encourage the education, employment, and training

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470/ U.S. Library of Congress. Congressional Research Service. Women in Science and Technology Careers. Issue Brief No. 80065, by Edith F. Cooper. May 29, 1980 (Archived, Apr. 21, 1982. Updated Apr. 23, 1982). Washington, 1980. p. 2.

of women in science and technology. Hearings were held in 1979 and 1980 by the Senate Committee on Labor and Human Resources, Subcommittee on Health and Scientific Research, in which concerns were expressed for providing equal opportunities for women in science.

On April 24, 1980, the subcommittee voted to send S. 568 to the full committee (Senate Committee on Labor and Human Resources) for consideration with an amendment incorporating S. 2462, which authorized appropriations for the NSF for fiscal years 1981 and 1982. On May 8, 1980, the provisions of S. 2462 were incorporated with S. 568, which later was reported favorably to the Senate with a written report (S. Rept. 96-713) and an amended title, the National Science Foundation and Women in Science Authorization Act for Fiscal Years 1981 and 1982. On June 23, 1980, the Senate passed S. 568 with amendments. On September 4, 1980, the House passed the measure with amendments. The House and Senate held two conferences to resolve disagreements concerning the amendments. Subsequently, the title of the bill was changed to the National Science Foundation Authorization and Science and Technology Equal Opportunities Act, which not only included provisions for women in science but for minorities and the handicapped in science as well. On December 2, 1980, the legislation was sent to the President, and was signed into Public Law 96-516 on December 12, 1980.

Congress appropriated $30.0 million to NSF to carry out the specifications of Part B of P.L. 96-516--Women, Minorities, Science and Technology, which stipulates that all underrepresented groups must be given equal opportunities to participate in science and technology and benefit regardless of race, color, creed, ethnic origin, or sex.

The following schedule was established for the implementation of portions of P.L. 96-516.

September 30, 1981: Deadline for the NSF Director to submit a report recommending programs to encourage the full participation of minorities in science and technology to the Senate Committee on Labor and Human Resources and the House Committee on Science and Technology;

January 20, 1982: By this date, the President was directed to report to Congress on a national policy for promoting equal opportunities for women and minorities in science, with the assistance of the NSF and Office of Science and Technology Policy (OSTP) Directors;

January 20, 1982: Deadline for the NSF Director's biennial report on employment statistics of women and minorities in scientific and technical positions, to be submitted to Congress, the Attorney General, the OSTP Director, the Equal Employment Opportunity Commission Chairman, the Office of Personnel Management Director, and the Secretaries of Labor, Education, and HHS; and

January 1, 1983: Deadline for the President, with the assistance of specified Federal officials, to report to Congress suggesting a national policy regarding the direct and indirect impact of science and technology and women and minorities.

6. The 97th Congress (Up to April 1982)

In April 1981, during the first session of the 97th Congress, the NSF Director, Dr. John Slaughter, announced that members of the Committee on Equal Opportunities in Science and Technology had been appointed, as suggested in part B, section 36 of the law, P.L. 96-516, to advise the NSF Director regarding the implementation of the Act "and on other policies and activities of the Foundation which are likely to result in greater participation of women in scientific, engineering, professional, and technical fields." Also reported during that month, was that the Reagan Administration had frozen funding for the NSF women and minorities in science programs, pending efforts to have it rescinded by Congress. In addition, the Administration also proposed to eliminate the programs entirely in 1982, 471/ along with NSF funding for science education programs. 472/

The fiscal year 1981 NSF budget for science education programs was originally $85.7 million, but this was reduced by the Reagan Administration to $67.6 million. 473/ The amount finally enacted was $70.6 million. 474/ The Supplemental Appropriations and Rescission Act, 1981, (P.L. 97-12) stipulates that "of the amounts remaining for science education activities under Public Law 96-526 [appropriations for fiscal year 1981 to the Department of Housing and Urban Development and specified independent agencies including NSF] not more than (1) $15,000,000 shall be available for women and minorities in science and technology activities, and (2) $500,000 shall be available for science education programs related to appropriate technology."

471/ Association for Women in Science Newsletter, v. 10, no. 2, Apr./May 1981. p. 3.

472/ Ibid., v. 10, no. 4, Aug./Sept. 1981. p. 3.

473/ Science and Engineering Education in NSF Budget. In Remarks of Don Fuqua. Congressional Record, Daily Edition, v. 127, July 22, 1981. p. E3642.

474/ Supplied by NSF during a telephone conversation with the Congressional Research Service, on Feb. 17, 1982.

For fiscal year 1982, the NSF was appropriated $20.9 million for science education, the lowest amount allotted for this function in almost 25 years. 475/ Essentially, science and engineering education programs would be discontinued in fiscal year 1982, "except for second and third year funding commitments for graduate fellowships already awarded." The NSF explained this reduction by stating, "[w]hen compared to total national expenditures for education in the United States, the Foundation's science and engineering program is relatively small, (less than one tenth of one percent of the total) . . . [a] number of the Foundation's science education goals are at least partially achieved through research support activities." 476/

During the first session of the 97th Congress, the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation held a day of hearings in Albuquerque, New Mexico. 477/ Conducted by Senator Harrison Schmitt, on the "Scientific and Technical Manpower Needs of New Mexico," testimony was presented by representatives of Federal research institutions, academia, and private industry. Senator Schmitt stated that the hearing would be "a good starting point to evaluate how successfully our school

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475/ Figure obtained during a telephone conversation in Apr. 1982 with a spokesman at the NSF.

476/ National Science Foundation. Budget in Brief to the Congress, Fiscal Year 1982. Washington, U.S. Govt. Print. Off., 1981. 69 p.

477/ U.S. Congress. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. Scientific and Technical Manpower Needs of New Mexico. Hearings, 97th Cong., 1st Sess., Feb. 9, 1981. Washington, U.S. Govt. Print. Off., 1981. 69 p.

systems and universities are training young men and women for the scientific and technical fields needed in private industry and governmental research." 478/

In October 1981, the House Committee on Science and Technology held two days of hearings on "Engineering Manpower Concerns." 479/ Witnesses representing academia, industry, and the Federal Government including the military, expressed their concerns regarding the condition of science and engineering education in the United States. The purpose of the hearings were twofold, as stated by committee chairman Representative Don Fuqua--(1) "to broadly define the extent of the problem now facing us in engineering and technical manpower"; and (2) "to explore the alternative solutions--realistic alternatives, other than simply putting more Federal dollars into more Federal programs." 480/

Consequently, Representative Fuqua introduced the National Engineering and Science Manpower Act of 1982 (H.R. 5254) that "authorizes each Federal agency and department to estabish programs for training technical and engineering personnel and to cooperate with State and local governments on such programs." It would also create a special Coordinating Council on Engineering and Scientific Manpower within the NSF to coordinate Federal efforts in science and engineering education. Referred to the House Committee on Science and Technology, two days of hearings were held concerning this bill on April 27, and 29, 1982.

478/ From a News Release by the Senate Committee on Commerce, Science, and Transportation, dated Feb. 2, 1981.

479/ U.S. Congress. House. Committee on Science and Technology. Engineering Manpower Concerns. Hearings, 97th Cong., 1st Sess., Oct. 6, 7, 1981. Washington, U.S. Govt. Print. Off., 1981. 174 p.

480/ Ibid., p. 1.

During the second session of the 97th Congress, the House Committee on Science and Technology, Subcommittee on Science, Research, and Technology held fiscal year 1983 NSF authorization hearings. 481/ Two days were set aside to discuss, especially, science and engineering education; plus women, minorities, and the handicapped in science; and scientific instrumentation. Of special concern was the fact that, for fiscal year 1983, the NSF has eliminated funding for all science education training programs. The only funding that NSF has requested is $15 million for graduate fellowships. Recognizing that there are problems in science education and disagreement on how to solve them, the NSF, according to its Director, Dr. John Slaughter, will "play a catalytic role, to help identify critical needs, and . . . encourage State and local governments, scientific and professional organizations, private industry, and other Federal agencies to make appropriate contributions to resolving them." 482/

In January 1982, the National Science Board (NSB), which is the policy-making body of the NSF, created a Commission on Pre-College Education in Mathematics, Science and Technology to "examine the health and potential of pre-college mathematics, science and pre-engineering education in the United States and make recommendations to the National Science Board and to the Nation

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481/ U.S. Congress. House. Committee on Science and Technology. Subcommittee on Science, Research, and Technology. National Science Foundation Authorization, Fiscal Year 1983. Hearings, 97th Cong., 2d Sess., Feb. 23, 25, Mar. 4, 1982. Unpublished.

482/ Taken from Dr. John B. Slaughter's testimony, presented at hearings before the Senate Committee on Labor and Human Resources on National Science Foundation Authorization for FY 1983, Apr. 15, 1982. p. 10.

as a whole to address identified needs." 483/ The Commission currently is funded by $700,000 awarded in fiscal year 1982. Additional funding for fiscal year 1983 has not been requested.

On March 25, 1982, the Senate Committee on Commerce, Science and Transportation held NSF authorization hearings for fiscal year 1983. Science and engineering education were among the topics discussed. Also, on April 15, 1982, the Senate Committee on Labor and Human Resources held hearings on NSF authorizations for fiscal year 1983. Several witnesses testified concerning science and engineering education concerns.

Two bills have been introduced concerning science and engineering education during the 97th Congress, second session, at the time of this writing. H.R. 5742 was introduced on March 4, 1982 by Representative Ike Skelton to create a National Commission on Science, Engineering, and Technology Education. It has been referred to several House committees--Committee on Armed Services, Subcommittee on Military Personnel and Compensation; Committee on Education and Labor, Subcommittees on Elementary, Secondary, and Vocational Education; on Select Education; and on Postsecondary Education. No further action has occurred. S. 2421, the National Engineering and Science Manpower and Education Act of 1982, by Senator John Glenn, was introduced on April 22, 1982 to create the National Coordinating Council on Technical, Engineering, and Scientific Manpower and Education, and for other purposes. Referred to the Senate Committee on Governmental Affairs, no further action has occurred at the time of this writing.

483/ National Science Foundation. Justification of Estimates of Appropriations to the Congress, Fiscal Year 1983. Washington, p. SEE-V-1.

II. RECAPITULATION

-- Congress has appropriated funds continuously to NSF in support of its science education activities through the Science and Engineering Education Directorate. 484/ Numerous bills have been introduced regarding science and engineering education over the 29-year period discussed in Part V of this report. Until the passage of the National Science Foundation Authorization and Science and Technology Equal Opportunities Act in 1980, Congress had not passed any substantial legislation focused specifically on science and engineering education, aside from the NSF appropriations to the Science and Engineering Education Directorate, since the enactment of the National Defense Education Act of 1958.

-- NSF has responded to the science and engineering education problem over the years by providing funding for scientific training of graduate students through graduate fellowships; establishing summer institutes for college teachers, which eventually expanded to include secondary- and elementary-level teachers; and creating its Course Content Improvement Program, its Women in Science Program, as well as various science education programs to assist minorities and the handicapped in science, and many more. Funding for NSF science education programs, however, dropped to the lowest amount in almost 25 years when, in fiscal year 1982 NSF was appropriated $20.9 million for that purpose. For fiscal year 1983, no funds have been proposed by the Administration for a science education program at the precollege level. NSF has requested, however, $15 million for graduate research fellowships;

484/ See appendix 16.

-- Before the launching of Sputnik I, there was significant congressional concern about the state of U.S. science education. Several forms of legislation were introduced between the 84th Congress and the end of the first session of the 85th Congress, immediately prior to the launching of the Soviet earth satellite. No definitive action occurred;

-- Following Sputnik I, public demand was aroused for more adequate science education instruction. Congress reacted through the passage of the National Defense Education Act in September 1958, which enacted a four-year, $887 million program for student loans, fellowships, and other aids to improve U.S. scientific manpower resources, including the strengthening of science and mathematics instruction and the establishment of a Science Information Service in the NSF; and

-- After the successful moon-landing mission of Apollo 11 in 1969, a large number of scientists and engineers lost their jobs, especially aerospace engineers. Within three years, between fall 1969 and fall 1972, engineering schools suffered a 29.7 percent decline in full-time freshmen enrollments, a 25.3 percent decrease in full-time sophomore enrollments, and a 9.0 percent decline in full-time junior enrollments. Substantial increases in engineering school enrollments did not become evident again until fall 1974. Since that time, as discussed in Part I of this report, undergraduate engineering school enrollments have continued to increase.

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PART I: SCIENTIFIC AND TECHNICAL EDUCATION IN THE UNITED STATES AS IT RELATES TO THE SUPPLY AND DEMAND OF SCIENCE AND ENGINEERING MANPOWER

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PART II: SCIENTIFIC AND TECHNICAL EDUCATION IN JAPAN, THE SOVIET UNION, AND WEST GERMANY

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Discusses the Japanese education system including administration, finance, and recent major education reforms of the system.

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This statistical handbook provides " a descriptive text, tables, charts and photographs . . . [used] to portray the actual conditions of modern Japan, covering political, economic, social and cultural fields."

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Vogel, Ezra F. Japan as number one: lessons for America. Cambridge, Massachusetts, Harvard University Press, 1979. 272 p. HN723.5.V63

The author states that the purpose of this book is to "describe selected aspects of the Japanese national system that are so effective that they contain lessons for America.

von Dohnanyi, Klaus. Education and youth employment in the Federal Republic of Germany. Carnegie Council on Policy Studies in Higher Education. Berkeley, California, The Carnegie Foundation for the Advancement of Teaching, 1978. 102 p.

"This is one of seven publications presenting studies commissioned by the Carnegie Council on Policy Studies in Higher Education as a means of providing a global perspective for education and youth employment in contemporary societies."

Wirszup, Izaak. The Soviet challenge. Educational leadership, v. 38, Feb. 1981: 358-360.

Discusses science and mathematics education in the Soviet Union and in the United States. The author warns that " . . . the recent Soviet educational mobilization . . . poses a formidable challenge to the national security of the United States. . . . "

PART III: ·POTENTIAL DIRECTIONS FOR SCIENCE AND TECHNOLOGY MANPOWER

Graham, Jim, LTC. The engineering shortage -- a national problem. Long Range Planning. Washington, U.S. Air Force.

Discusses the current and future projections of supply and demand of science and engineering manpower in the Nation and the implications for the U.S. Air Force.

Scientific, Engineering, Technical Manpower Comments, v. 18, nos. 2 and 3, March and April 1981.

Continuously updated publication prepared by the Scientific Manpower Commission that provides current information regarding scientific and technological concerns of the Nation.

PART IV: THE SUPPLY OF DEPARTMENT OF DEFENSE SCIENTISTS AND ENGINEERS IN THE UNITED STATES

Katonak, Major Thomas T., USAF. The engineer shortage: an analysis. Executive summary. Report no. 1365-81. Washington, 1981. 41 p.

The author assesses "the current and projected shortage of engineers in the U.S. Air Force Officer Corps and analyze potential solutions to ameliorate the shortage."

Office of the Under Secretary of Defense. The status of scientific and engineering personnel in the United States: analysis of the problem, its impact on DoD, and the role of the defense in the national arena. White paper report. Washington, 1981. 5 p.

Summarizes the issue of supply and demand of scientific and engineering manpower in the United States. Reviews the impact on the Department of Defense.

U.S. Library of Congress. Congressional Research Service. Engineering manpower: a survey of the national problem and the problem in the Department of Defense. By Paul Zinsmeister. Dec. 21, 1981. Washington, 1981. 19 p.

Surveys the current situation of the perceived shortage of science and engineering manpower at the national level and within the Department of Defense.

PART V: A HISTORY OF CONGRESSIONAL CONCERN AND SOME ACTIONS TAKEN BY THE NATIONAL SCIENCE FOUNDATION RELATED TO SCIENCE AND ENGINEERING EDUCATION

Anderson, Clinton P. Remarks in the House. Congressional record [daily ed.] v. 101, July 11, 1955: 10151-10152.

Remarks in the House of Clinton P. Anderson regarding the loss of high school science teachers to industry because of higher salaries, that was evident in 1955, and the effect on science instruction at the high school level.

Bates, Dorothy M. Analysis of legislation related to improvement of scientific study, teaching, and progress in the United States: 79th Congress to the 85th Congress, 1st session, 1945-1957. In U.S. Congress. Senate. Committee on Government Operations. Science and Technology Act of 1958. Washington, U.S. Govt. Print. Off., 1958. pp. 152-177. (85th Congress, 2d session. Senate. document no. 90)

An analysis of proposed legislation "that dealt with the overall reorganization of governmental scientific activities, the training of scientists and engineers in particular, and aid to higher education in general" for each session of Congress beginning with the 79th Congress, 1st session through the 85th Congress, 1st session.

Cannon, Howard W. The nation's scientific manpower policies. Remarks in the Senate. Congressional record [daily ed.] v. 109, Feb. 7, 1963: 2055-2056.

During remarks in the Senate, the Senator expressed his concern that nothing concrete had been done at that time to combat the problem of a shortage of engineers and scientists in the Nation.

DeWitt, Nicholas. Professional and scientific personnel in the U.S.S.R. Science, v. 120, July 2, 1954: 1-4.

Summarizes findings from a study, The Soviet professional labor force, 1928-1953, that revealed information about Soviet professional and scientific manpower problems during that time period.

Engineering Manpower Commission. Engineers Joint Council. Engineering and technology enrollments, fall 1978. Part I, enrollments by schools, enrollments by curriculum for all students. New York, Engineers Joint Council, Jan. 1979. 189 p.

A compilation of statistical data for all students enrolled in engineering technology programs by curricula and school, covering 276 engineering schools across the Nation. This information is updated for the fall of each school year.

Hartsfield, Jack. Gold mine of local talent just sits. In Remarks of James B. Allen. Congressional record [daily ed.] v. 116, Aug. 21, 1970: 29694-29696.

An article taken from the Huntsville (Alabama) Times discussing impending layoff of scientists and engineers who were involved in the space program.

Husen, Torsten, ed. International study of achievement in mathematics: a comparison of twelve countries. Vol II. New York, John Wiley and sons, 1967. 368 p.

Reports findings of a 12-nation educational endeavor to compare student-achievement in mathematics. U.S. pupils were found to rank low in mathematical achievement compared with students from Japan, England, France, Sweden, and Belgium.

Kelly, Harry C. Trends in supply of scienitists and engineers in the United States. Science, v. 120, July 2, 1954: 5A.

Discusses the number of science and engineering students enrolled in U.S. colleges and universities, the number of scientists and engineers employed in the labor force, and notes that slightly less than 0.5 percent of the U.S. total population were scientists and engineers, at that time. Also compared similar statistics of the Soviet Union, and observed that the Soviets placed greater emphasis on training in science and technology.

Killian, James R., Jr. Can Government maintain vital scientific leadership? A public service report of the National Civil Service League, New York, 1963. 16 p.

Discusses the problem of the Federal Government, as well as the Nation's, of keeping adequate numbers of scientists and engineers in order "to keep pace with the growing size of . . . national commitments in science and technology."

Lack of scientists is called critical: 2d report of U.S. Foundation says Russia is outdistancing us in engineering graduates. New York times, Jan. 17, 1953.

Discusses findings from the second annual report of the NSF that found that there was a shortage of scientists and engineers in the Nation and predicted that Russia would graduate more engineers than the United States.

Lomask, Milton. A minor miracle: an informal history of the National Science Foundation. Washington, U.S. Govt. Print. Off., 1976. NSF 76-18. 285 p.

"This account of the first 25 years of the National Science Foundation is a selective one . . . [that] consists of episodes and developments chosen from a large number of possibilities in an effort to convey to the general reader the flavor of a unique public institution.

MacDougall, A. Kent. Recruiting aborad: U.S. concerns step up overseas search for scientists, engineers. Wall street journal, Apr. 23, 1962: 1, 6.

Discusses efforts to recruit scientists and engineers in other countries by an increasing number of U.S. industries because of a lack of such personnel in the United States.

Malabre, Alfred L., Jr. Uneasy engineers -- many seek to acquire new skills as demand softens, layoffs mount -- defense cutbacks big factor; firms curb stockpiling of engineers to cut costs -- rush back to the classroom. In remarks of James W. Fulbright. Congressional record [daily ed.] v. 110, Feb. 27, 1964: 3808-3810.

The article suggests that there may have been a surplus of engineers, at that time, at least in the defense and space industries. There was apparently "a current slump in demand for engineers . . . [resulting] primarily from uncertainty about future spending on defense and space programs."

Pell, Claiborne. The expected shortage of engineers. Remarks in the Senate. Congressional record [daily ed.] v. 113, June 6, 1967: 14754-14755.

Emphasizes that the Nation did not have adequate numbers of engineers to insure that it would have the necessary supply of such trained manpower in years to come.

Price, Melvin. Meeting the need for scientific manpower -- an intelligent approach to the problem. Remarks in the House. Congressional record [daily ed.] v. 104, Feb. 3, 1958: 1572-1574.

Discusses the shortage of science and engineering manpower, the threat of the Soviet Union as a result of the launching of Sputnik I, previous hearings held prior to Sputnik that acknowledged concerns about the Soviet scientific and technical manpower and abilities, and proposes means by which high school science and mathematics teachers can improve the quality of instruction in these subject areas.

United States ranked low in math teaching. In remarks of John Brademas. Congressional record [daily ed.] v. 113, March 7, 1967: 5734-5736.

Several articles were placed in the record by Mr. Brademas who reported on the outcome of an international comparison of student-achievement in mathematics in which U.S. students lagged behind five other nations, including Japan.

U.S. Congress. House. Committee on Science and Astronautics. Subcommittee on Science, Research, and Development. The National Science Foundation: A general review of its first 15 years. Report prepared by the Science Policy Research Division, Legislative Reference Service, Library of Congress, 89th Congress, 2d session. Washington, U.S. Govt. Print. Off., 1966. 286 p.

A general review of the first 15 years of the National Science Foundation, 1950 to 1965. "Included is [a] discussion of basic research project grants, national research programs, support of research facilities, science education and institutional programs, science information services, and support of science policy planning."

----- Committee on Science and Technology. Subcommittee on Science, Research and Technology. The National Science Foundation and Pre-college science education: 1950-1975. Washington, U.S. Govt. Print. Off., 1975. 297 p.

"This study examines the situations and events which led the National Science Foundation into an involvement with educational activities and with the teaching of science at the pre-college level, and which have shaped the Foundation's educational programs at the pre-college level over the past 25 years."

----- National Science Foundation authorizations for fiscal year 1983. Hearings, 97th Congress, 2d session, Feb. 23, 25, March 4, 1982. Unpublished.

Two days of the three day hearings dealt specifically with science and engineering education, women, minorities, and the handicapped in science, and scientific instrumentation. Of special concern was the fact that for fiscal 1983, the NSF has not proposed funding for science education programs.

----- Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space.

Legislative record: digest of achievements and status of presidential recommendations, 86th Congress, 1st session, January 7, 1959, to September 15, 1959. Five-year review of the democratic controlled 84th, 85th, and 86th Congresses [by the Honorable Lyndon B. Johnson, Senate Majority Leader] Washington, U.S. Govt. Print. Off., 1959. (86th Congress, 1st session. Senate. Document no. 63) 159 p.

A summary of congressional achievements from January 1955 to the end of the 86th Congress, 1st session, Jan. 1959. During this period, Congress passed the National Defense Education Act of 1958.

----- National Science Foundation authorization. Hearings, 97th Cogresss, 2d session. Washington, U.S. Govt. Print. Off., 1982. 67 p.

A day of hearings was held on Mar. 25, 1982 to discuss fiscal year 1983 authorizations for the National Science Foundation. Science and technology education and manpower issues were discussed.

----- Scientific and technical manpower needs of New Mexico. Hearings, 97th Congress, 1st session. Feb. 9, 1981. Washington, U.S. Govt. Print. Off., 1981. 69 p.

A day of hearings was held in Albuquerque, New Mexico as "a starting point to evaluate how successfully . . . [the Nation's] school systems and universities are training young men and women for the scientific and technical fields needed in private industry and governmental research."

----- Summary of the three-year Kennedy record and digest of major accomplishments of the eighty-seventh Congress and the eighty-eighth Congress, first session, January 3, 1961, to December 30, 1963. Together with a statement by the Honorable Mike Mansfield, Senate Majority Leader. Washington, U.S. Govt. Print. Off., 1964. 303p. 88th Congress, 1st session. Senate. Document no. 53)

As a result of the assassination of President John F. Kennedy in November 1963, this analysis of congressional achievements was enlarged to include the three-year record of the Kennedy administration. In 1962, the Office of Science and Technology was established within the Executive Office of the President. Among other duties, the OST staff was charged to keep a close relationship with the science and engineering community in order to further its participation in strengthening the nation's science and technology and that of the free world.

U.S. Library of Congress. Congressional Research Service. Women in science and technology careers: background analysis and legislative concerns. By Edith Fairman Cooper. Apr. 25, 1980. Washington, 1980. 85 p.

Women scientists, especially with doctorate degrees, constitute a very small proportion of all scientists in the science and technology professions and are relatively a large base of untapped talent for science and technology fields. This report provides a background discussion about this issue.

----- Women in science and technology careers. Issue brief no. 80065, by Edith F. Cooper. May 29, 1980. (Archived Apr. 21, 1981). Washington, 1980. 8 p.

Provides an overview of the issue concerning the participation of women in scientific and technological careers.

----- Legislative Reference Service. Legislation dealing with science and technology, 85th Congress, 2d session, 1958. Compiled by Dorothy M. Bates, Analyst in American Government and Public Administration, Oct. 15, 1963. 5 p.

This is a compilation of legislation dealing with science and technology that was enacted during the second session of the 85th Congress which began three months after Sputnik I was launched.

Venn, Grant. Man, education, and work: postsecondary vocational and technical education. Washington, American Council on Education, 1964. 184 p. LC1043.V4

"It is the thesis of this report that technology has created a new relationship between man, his education, and his work, in which education is placed squarely between man and his work." The author contends that "unless far more and far better education on the semiprofessional, technical, and skilled levels is soon made available to greater numbers of citizens, the national economy and social structure will suffer irreparable damage."

Waterman, Alan T. Statement of Alan T. Waterman, Director, National Science Foundation, before the Subcommittee on Independent Offices, Senate Appropriations Committee, Apr. 24, 1953. In remarks of H. Alexander Smith. Congressional record, [daily ed.] v. 100, May 5, 1953: 4438-4440.

During his statement before the Senate Appropriation's Subcommittee, Dr. Waterman explained that the NSF was providing financial assistnace for the training of scientists and engineers to help ease the shortage of such personnel evident in the Nation at that time.

APPENDICES

APPENDIX 1a

PERCENT OF STATES REQUIRING LESS THAN 1 YEAR, 1 YEAR, AND MORE THAN 1 YEAR OF EACH SUBJECT IN GRADES 9 THROUGH 12 FOR HIGH SCHOOL GRADUATION, BY REGION AND SIZE OF STATE

	Mathematics			Science				Social Studies			
	Less Than 1 Year	1 Year	More Than 1 Year	Less Than 1 Year	1 Year	More Than 1 Year	Unknown	Less Than 1 Year	1 Year	More Than 1 Year	Unknown
Nation	22	57	21	12	53	21	15	2	17	68	13
Region[1/]											
Northeast	57	29	14	0	38	13	50	13	25	38	25
South	7	53	40	6	56	38	0	0	13	81	6
North Central	18	82	0	25	42	8	25	0	25	58	17
West	20	60	20	15	69	15	0	0	9	82	9
Size of State											
Small	21	64	15	12	57	18	13	0	21	74	6
Medium	13	62	25	11	55	23	11	6	17	77	0
Large	33	44	24	13	66	21	21	0	13	52	35
Sample N		43			49				47		

SOURCE: Weiss, Iris R. Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education, p. 24.

[1/] Regions

Northeast : CT, ME, MA, NH, NJ, NY, PA, RI, VT

South : AL, AR, DE, DC, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV

North Central: IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, WI

West : AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY

APPENDIX 1b

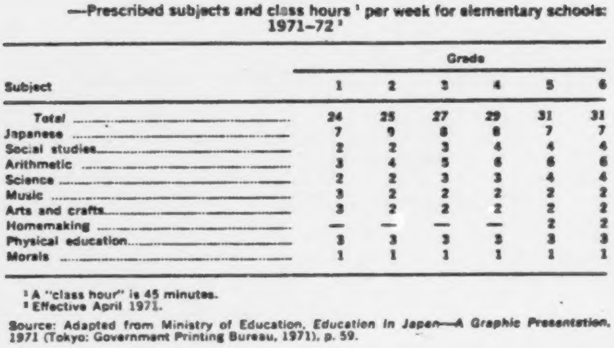
AVERAGE NUMBER OF MINUTES PER DAY SPENT IN ELEMENTARY SCHOOL MATHEMATICS, SCIENCE, AND SOCIAL STUDIES LESSONS, BY GRADE RANGE 1/

	Subject					
	Mathematics		Science		Social Studies	
Grade Range	Minutes	Standard Error	Minutes	Standard Error	Minutes	Standard Error
K-3 (N=801)	38	2.53	19	4.12	22	1.84
4-6 (N=805)	44	2.09	35	1.73	40	4.62

1/ Classes in which the most recent lesson was not on the last day school was in session were assigned zeros for number of minutes spent in the lesson.

SOURCE: Weiss, Iris R. Report of the 1977 National Survey of Science, Mathematics, and Social Studies Education, p. 50.

APPENDIX 2



—Prescribed subjects and class hours [1] per week for elementary schools: 1971–72 [2]

Subject	Grade 1	2	3	4	5	6
Total	24	25	27	29	31	31
Japanese	7	9	8	8	7	7
Social studies	2	2	3	4	4	4
Arithmetic	3	4	5	6	6	6
Science	2	2	3	3	4	4
Music	3	2	2	2	2	2
Arts and crafts	3	2	2	2	2	2
Homemaking	—	—	—	—	2	2
Physical education	3	3	3	3	3	3
Morals	1	1	1	1	1	1

[1] A "class hour" is 45 minutes.
[2] Effective April 1971.

Source: Adapted from Ministry of Education, *Education in Japan—A Graphic Presentation, 1971* (Tokyo: Government Printing Bureau, 1971), p. 59.

SOURCE: Anderson, Ronald S. Education in Japan: A Century of Modern Development, p. 114.

APPENDIX 3

TABLE 1 -- Sample [of Japanese] Senior High School General Program, College Preparatory Course;

TABLE 2 -- Sample [of Japanese] Senior High School General Program, Terminal Course;

TABLE 3 -- Sample [of Japanese] Senior High School Vocational Program, Industrial Arts (Mechanical Specialty);

TABLE 4 -- Sample [of Japanese] Senior High School Vocational Program, Business.

SOURCE: Anderson, Ronald S. Education in Japan, p. 150-153.

TABLE 1

—Sample senior high school general program, college preparatory course: 1973–74[1]

Area	Subject[2]	Year 1	Year 1 or 2	Year 2	Year 2 or 3	Year 3	Total credits for area
Grand total							102
	Curricular						
Total							[1]91
Japanese language	Modern Japanese	3		2		2	
	Classics I–B	2		3			15
	Classics II					3	
Social studies	Ethics-civics				2		
	Political science-economics				3		
	Japanese history				3		18
	World history		4				
	Geography A Geography B		3				
Mathematics	Mathematics I	6					
	Mathematics II–B			5			14
	Mathematics III					5	
Science	Physics I Chemistry I	3		3			
	Biology I Earth science I	3		3			15
	Physics II Chemistry II Biology II Earth science II					3	
Health and physical education	Health and physical education						
	Boys	4		4		3	13
	Girls	2		2		3	9
Fine arts	Music I Fine arts I Handicrafts I Calligraphy I	2					
	Music I Fine arts I Handicrafts I Calligraphy I Music II Fine arts II Handicrafts II Calligraphy II			2			4
Foreign language	English B German French Other language	5		5		5	15
Homemaking (girls)	General homemaking	2		2			4
	Noncurricular						
Total							11
Homeroom and club activities		2		2		2	6
Additional credits							5

[1] Effective April 1973.

[2] "A" means a general study of the subject; "B" means an advanced study of it. "I" and "II" indicate a sequence of courses; "I" is prerequisite to "II."

Source: Adapted from Agency for Cultural Affairs, *Outline of Education in Japan* (Tokyo: the Agency, 1972), p. 22.

TABLE 2

—Sample senior high school general program, terminal course: 1973–74[1]

Areas	Subjects[2]	Years: 1st year		Years: 2d year		Years: 3d year	Total for area
Japanese language	Modern Japanese	3		3		4	
	Classics I–A	2					15
	Classics II				3		
Social studies	Ethics-civics				2		
	Political science-economics				3		
	Japanese history				3		16
	World history		4				
	Geography B		4				
Mathematics	Mathematics I	3		3			
	Mathematics II–A					4	10
Science	Physics I Chemistry I Biology I Earth science I	3		3		3	9
Health and physical education	Health		2				
	Physical education						
	Boys	4		4		4	(B)14
	Girls	2		2		4	(G)10
Fine arts	Music I Fine arts I Handicrafts I Calligraphy I Music II Fine arts II Handicrafts II Calligraphy II			2			
	Music I Fine arts I Handicrafts I Calligraphy I Music II Fine arts II Handicrafts II Calligraphy II Music III Fine arts III Handicrafts III Calligraphy III				2		6
Foreign language	One of the following:						
	English A	3		3		3	
		or					
	Elementary English or English conversation	2		2		2	3–9
		or					
	English conversation	3					
Homemaking (girls)	General homemaking	2		2			
	Other homemaking					2	(G)6
Vocational subjects	Boys						6–15
	Girls						7–13
		(over the 3-year period)					
Homeroom and club activities		2		2		2	6
Additional elective credits							8

[1] Effective April 1973.

[2] "A" means a general study of the subject; "B" means an advanced study of it. "I" and "II" indicate a sequence of courses; "I" is prerequisite to "II."

Source: Adapted from Agency for Cultural Affairs, *Outline of Education in Japan* (Tokyo: the Agency, 1972), p. 22.

TABLE 3

—Sample senior high school vocational program, industrial arts (mechanical specialty): 1973–74[1]

Areas	Subjects[2]	Total credits in years 1, 2, & 3
Grand total		100–05
General Subjects Total		51
Japanese language	Modern Japanese	7
	Classics I–A	2
Social studies	Ethics-civics	2
	Political science–economics	2
	Japanese history or world history	3
	Geography A or geography B	3
Mathematics	Basic mathematics or mathematics I	6
	Applied mathematics	3
Science	Basic science or one of the following: physics I, chemistry I, biology I, and earth science	6
Health and physical education	Health	2
	Physical training	7
Fine arts	Music I or fine arts I or handicrafts I or calligraphy I	2
Foreign language	Elementary English or English A	6
Vocational Subjects Total		43–48
	Machine-shop practice	14
	Mechanical drawing	9
	Machine design	7
	Machine-shop theory	6
	Prime mover	3
	Industrial measurement automatic control	2
	Materials for machine works or industrial management or general electricity or industrial English	2–7
Homeroom and Club Activities Total		6

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[1] Effective April 1973.

[2] "A" means a general study of the subject; "B" means an advanced study of it. "I" and "II" indicate a sequence of courses; "I" is prerequisite to "II."

Source: Adapted from Agency for Cultural Affairs, *Outline of Education in Japan* (Tokyo: the Agency, 1972), p. 24.

TABLE 4

—Sample senior high school vocational program, business: 1973–74[1]

Areas	Subjects[2]	Total credits in years 1, 2, and 3
Grand total		101–103 Boys (B) 105–107 Girls (G)
General Subjects Total		57 (B) 61 (G)
Japanese language	Modern Japanese	7
	Classics I–A	2
Social studies	Ethics-civics	2
	Political science–economics	2
	Japanese history or world history	3
	Geography A or geography B	3
Mathematics	Basic mathematics or mathematics I	6
Science	Basic science or one of the following: physics I, chemistry I, biology I, and earth science	6
Health and physical education	Health	2
	Physical training	7
Fine arts	Music I or fine arts I or handicrafts I or calligraphy I	2
Foreign language	English A or English B	15
Domestic arts	General homemaking	4 (G)
Vocational Subjects Total		38–40
	General business	3
	Business management	3
	Business law	3
	Bookkeeping and accounting I	4
	Bookkeeping and accounting II	2
	Bookkeeping and accounting III	3
	Industrial bookkeeping	3
	Bank bookkeeping	2
	Machine bookkeeping	4
	Tax bookkeeping	2
	Accounting practice	4
	Business calculation	5–7
Homeroom and Club Activities Total		6
Homeroom and club activities		6

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[1] Effective April 1973.

[2] "A" means a general study of the subject; "B" means an advanced study of it. "I" and "II" indicate a sequence of courses; "I" is prerequisite to "II."

Source: Adapted from Agency for Cultural Affairs, *Outline of Education in Japan* (Tokyo: the Agency, 1972), p. 25.

APPENDIX 4

TABLE 5

U.S. BACHELOR'S DEGREES AND U.S.S.R. DIPLOMAS CONFERRED BY HIGHER EDUCATIONAL INSTITUTIONS,
BY MAJOR FIELD OF STUDY: 1960-1979
(In thousands)

Year	1960		1965		1970		1975		1976		1977		1978		1979	
	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.
All Fields, Total[1]	394.9	343.3	538.9	403.9	833.3	630.8	987.9	713.4	997.5	734.6	993.0	751.9	997.2	771.5	NA	790.0
Science and Engineering, Total	89.4	162.5	109.2	211.8	147.6	326.5	161.4	370.9	164.4	383.4	168.7	397.9	174.0	607.7	NA	416.9
Physical and Life Sciences and Mathematics[2]	45.3	(25.1)	65.7	(25.6)	91.4	(39.7)	96.5	(44.9)	98.2	(46.3)	97.5	(47.8)	95.3	49.0	NA	49.8
Engineering	37.8	102.9	36.8	152.3	44.8	230.5	47.3	272.1	46.7	280.4	49.7	291.4	56.0	300.1	NA	306.8
Agriculture	6.3	34.5	6.8	33.9	11.4	58.3	17.6	53.9	19.5	56.7	21.5	58.7	22.7	58.6	NA	60.3

Percent of 22/23 Year Old Population[3]

Year	1960		1965		1970		1975		1976		1977		1978		1979	
	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.	U.S.	U.S.S.R.
All Fields, Total	17.6	7.8	18.1	13.3	23.9	19.3	26.0	16.4	25.6	17.1	25.1	16.8	24.9	16.2	NA	16.4
Science and Engineering, Total	4.0	3.7	3.7	7.0	4.2	10.1	4.3	8.5	4.2	8.9	4.3	8.9	4.3	8.6	NA	8.7
Physical and Life Sciences and Mathematics[2]	2.0	(0.6)	2.2	(0.8)	2.6	(1.2)	2.5	(1.0)	2.5	(1.1)	2.5	(1.1)	2.4	1.0	NA	1.0
Engineering	1.7	2.3	1.2	5.0	1.3	7.1	1.2	6.2	1.2	6.5	1.3	6.5	1.4	6.3	NA	6.4
Agriculture	0.3	0.8	0.2	1.1	0.3	1.0	0.5	1.2	0.5	1.3	0.5	1.3	0.6	1.2	NA	1.3

[1] Includes first professional degrees for U.S.

[2] Figures for the U.S.S.R. are estimates based on two-thirds of graduation in "university specialties" to which graduation in geology-prospecting, geodesy-cartography, and hydrology-meteorology have been added to approximate U.S. definitions.

[3] Percent of 22 year olds for the U.S. and 23 year olds for the U.S.S.R., due to differences in average length of years required to graduate from higher education.

Sources: Earned Degrees Conferred, National Center for Education Statistics, Department of Health, Education and Welfare, Annual Series;
National Economy of the USSR in 1970, p. 646 and 1979, p. 500;
U.S.S.R. population data from Foreign Demographic Analysis Division, U.S. Bureau of Census;
U.S. population data from Population Division, U.S. Bureau of Census.

SOURCE: Ailes, Catherine P. and Francis W. Rushing. The Science Race: Training and Utilization of Scientists and Engineers, U.S. and U.S.S.R., p. 68.

APPENDIX 5

TABLE 6

U.S. AND U.S.S.R. EDUCATIONAL ATTAINMENT OF THE POPULATION: 1960-1977

	1960	1970	1975	1976	1977
U.S.[1]			Percent		
College, 4 Years or More	7.7	11.0	13.9	14.7	15.4
High School, 4 Years or More	33.4	44.2	48.6	49.4	49.5
Fifth Grade, or More	50.6	39.5	33.3	32.0	31.4
Less than 5 Years of School	8.3	5.3	4.2	3.9	3.7
			Number of Years		
Median Level	10.6	12.2	12.3	12.4	12.4
U.S.S.R.[2]			Percent		
Higher	2.8	5.0	6.2	6.4	6.7
Incomplete Higher	1.2	1.6	1.5	1.6	1.5
Specialized Secondary	5.7	8.0	9.8	10.1	10.4
General Secondary	7.4	14.0	17.6	18.6	19.8
Incomplete Secondary	23.3	26.8	27.6	27.4	27.1
Primary and Less	59.6	44.6	37.3	35.9	34.5
			Number of Years		
Median Level	5.8	7.6	8.3	8.5	8.7

[1] Data for persons 25 years of age or older.
[2] Data for persons 16 years of age or older.

Sources: Statistical Abstract of the United States, 1978, p. 143;
USSR: Trends and Prospects in Educational Attainment, 1959-85,
National Foreign Assessment Center, ER79-10344, p.7, 23 (June 1979).

SOURCE: Ailes, Catherine P. and Francis W. Rushing. The Science Race, p. 15.

APPENDIX 6.

TABLE 7 -- Science and Engineering Degrees Awarded in West Germany, 1978-79.

16.8 Prüfungen an Hochschulen*)

Fächergruppe Studienbereich	Abgelegte Prüfungen im									
	Prüfungsjahr 1978[1]					Prüfungsjahr 1979[1]				
	Deutsche			Ausländer		Deutsche			Ausländer	
	insgesamt	bestanden zusammen	bestanden weiblich	insgesamt	bestanden	insgesamt	bestanden zusammen	bestanden weiblich	insgesamt	bestanden
Diplom- und entsprechende Abschlußprüfungen										
Sprach- und Kulturwissenschaften	6 124	5 718	2 660	409	371	5 822	5 414	2 466	419	358
dar.: Theologie, Religionslehre	760	722	108	30	29	948	889	157	24	24
Psychologie	1 423	1 355	645	42	39	1 319	1 285	696	49	47
Sport	204	204	71	23	22	243	238	76	18	18
Wirtschafts- und Gesellschaftswissenschaften	16 085	12 973	2 645	452	362	15 910	12 988	3 005	429	325
dar.: Rechtswissenschaft	5 519	4 167	992	32	21	6 498	4 933	1 302	25	16
Wirtschaftswissenschaften	8 524	6 828	1 071	284	218	7 342	6 083	1 058	275	199
Mathematik, Naturwissenschaften	6 374	6 045	1 343	371	348	6 194	5 936	1 425	385	365
dar.: Mathematik	1 198	1 097	139	45	44	1 213	1 125	152	26	24
Physik, Astronomie	1 596	1 048	51	42	39	1 080	1 047	55	52	48
Chemie	1 277	1 235	191	122	111	1 107	1 082	214	103	96
Pharmazie	1 081	1 002	555	37	33	1 036	963	498	49	45
Humanmedizin	3 941	3 898	936	190	179	7 413	7 233	2 013	364	342
dar.: Zahnmedizin	1 061	1 046	184	35	35	1 111	1 103	251	52	52
Veterinärmedizin	486	486	151	56	56	423	423	184	28	28
Agrar-, Forst- und Ernährungswissenschaften	1 375	1 247	530	92	82	1 486	1 353	598	69	60
Ingenieurwissenschaften	6 348	5 806	353	754	651	6 562	5 879	359	711	624
dar.: Maschinenbau/Verfahrenstechnik	1 887	1 759	41	254	220	1 835	1 686	34	229	202
Elektrotechnik	1 560	1 399	20	139	112	1 803	1 519	9	219	184
Kunst, Kunstwissenschaft	1 139	1 110	511	254	253	984	972	456	236	234
Sonstige Fächer	13	11	—	10	7	—	—	—	—	—
Insgesamt	**42 089**	**37 498**	**9 200**	**2 611**	**2 331**	**45 037**	**40 436**	**10 582**	**2 659**	**2 354**
Doktorprüfungen										
Sprach- und Kulturwissenschaften	1 213	1 208	269	123	120	1 022	1 019	269	129	122
Sport	6	6	1	—	—	8	8	3	—	—
Wirtschafts- und Gesellschaftswissenschaften	1 228	1 221	90	68	67	1 159	1 150	113	78	77
dar.: Rechtswissenschaft	497	493	32	17	17	459	452	43	11	11
Wirtschaftswissenschaften	472	469	27	17	17	424	422	32	32	32
Mathematik, Naturwissenschaften	2 367	2 363	219	229	227	2 470	2 467	272	249	247
dar.: Physik, Astronomie	504	504	7	37	36	539	539	12	33	33
Chemie	982	979	55	96	96	976	976	74	88	88
Humanmedizin	4 476	4 470	1 013	279	279	4 827	4 827	1 208	234	234
dar.: Zahnmedizin	853	852	151	39	39	777	777	138	38	38
Veterinärmedizin	249	248	73	38	38	257	257	92	28	28
Agrar-, Forst- und Ernährungswissenschaften	241	241	39	86	86	212	212	52	70	69
Ingenieurwissenschaften	920	920	8	122	122	983	982	5	116	116
Kunst, Kunstwissenschaft	128	128	57	11	11	110	110	49	13	13
Sonstige Fächer	—	—	—	—	—	1	1	1	—	—
Insgesamt	**10 828**	**10 805**	**1 769**	**956**	**950**	**11 049**	**11 033**	**2 064**	**917**	**906**
Lehramtsprüfungen[2]										
Sprach- und Kulturwissenschaften	43 762	40 540	25 623	316	294	38 276	35 144	22 493	186	163
dar.: Theologie, Religionslehre	2 126	2 039	1 275	5	4	2 082	1 986	1 293	3	3
Geschichte	4 143	3 701	1 821	23	20	3 581	3 241	1 529	15	12
Germanistik (Deutsch, germanische Sprachen ohne Anglistik)	9 682	9 129	5 938	104	100	7 977	7 489	4 799	34	30
Anglistik, Amerikanistik	5 145	4 578	3 110	56	49	4 646	4 059	2 723	28	26
Romanistik	2 205	1 874	1 445	46	40	2 317	1 958	1 474	36	30
Erziehungswissenschaften	17 457	16 224	10 527	52	50	14 398	13 490	9 038	45	39
Sport	3 944	3 679	1 745	21	17	3 697	3 468	1 620	21	20
Wirtschafts- und Gesellschaftswissenschaften	7 742	7 255	2 978	17	17	5 535	5 151	2 292	10	9
dar.: Politik- und Sozialwissenschaften	5 920	5 599	2 413	11	11	4 312	4 053	1 859	7	6
Wirtschaftswissenschaften	1 710	1 548	509	6	6	850	735	239	3	3
Mathematik, Naturwissenschaften	18 138	15 997	8 113	105	91	15 791	13 827	6 958	52	51
dar.: Mathematik	6 795	5 827	2 974	43	38	5 750	4 843	2374	20	20
Biologie	3 246	3 026	1 979	20	17	2 887	2 690	1 738	13	13
Geographie	4 208	3 799	2 018	23	19	3 438	3 047	1 591	8	7
Agrar-, Forst- und Ernährungswissenschaften	545	524	470	4	4	445	436	390	3	3
Ingenieurwissenschaften	1 471	1 364	109	3	3	1 444	1 317	162	3	3
Kunst, Kunstwissenschaft	4 988	4 804	3 244	27	26	4 637	4 479	3 101	21	21
Sonstige Fächer	123	124	6	—	—	1	1	—	—	—
Insgesamt	**80 713**	**74 287**	**42 288**	**495**	**452**	**69 826**	**63 823**	**37 016**	**296**	**270**
Graduierungen										
Sprach- und Kulturwissenschaften	1 107	1 061	663	14	8	865	807	551	24	20
Wirtschafts- und Gesellschaftswissenschaften	10 923	10 121	4 167	271	164	14 870	13 847	5 759	173	162
dar.: Sozialwesen	5 236	5 045	3 297	68	67	6 689	6 477	4 065	77	77
Wirtschaftswissenschaften	4 693	4 126	668	183	78	4 367	3 870	687	70	62
Mathematik, Naturwissenschaften	398	386	97	17	16	798	772	149	50	48
Agrar-, Forst- und Ernährungswissenschaften	1 077	1 018	247	41	39	1 418	1 356	409	43	39
Ingenieurwissenschaften	16 683	15 771	1 346	997	930	15 978	14 993	1 192	998	912
dar.: Maschinenbau/Verfahrenstechnik	5 822	5 581	281	459	432	5 678	5 405	273	450	423
Elektrotechnik	5 133	4 885	87	178	169	4 728	4 484	57	184	174
Architektur, Innenarchitektur	2 656	2 456	769	208	195	2 276	2 076	663	181	155
Bauingenieurwesen	2 304	2 123	174	141	123	2 251	2 022	132	151	132
Kunst, Kunstwissenschaft	1 160	1 133	563	53	51	1 098	1 067	592	55	54
Sonstige Fächer	83	83	[illegible]	—	—	—	—	—	—	—
Insgesamt	**31 431**	**29 573**	**7 [illegible]**	**1 393**	**1 208**	**35 027**	**32 842**	**8 652**	**1 343**	**1 235**

Diploma

Dipl.-Ing

Ph.D

Ph.D

Teachers for higher schools

Ing. grad

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*) Einschl. Abschlußprüfungen an staatlichen und kirchlichen Prüfungsämtern.

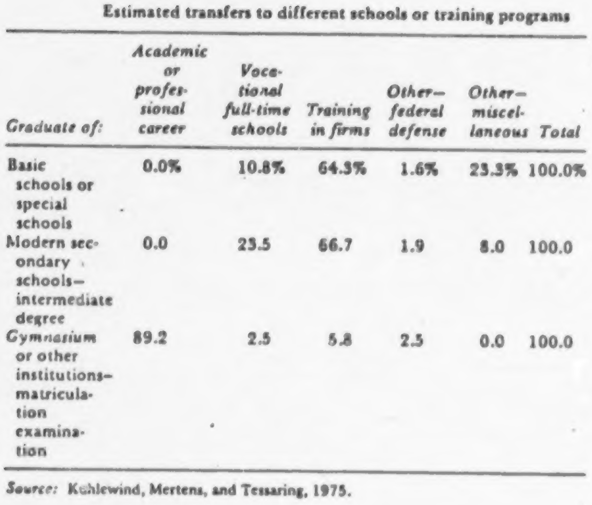
[1] Prüfungsjahr = Wintersemester und darauffolgendes Sommersemester.

[2] Erste Staatsprüfung für das Lehramt sowie Zusatz-, Ergänzungs- oder Erweiterungsprüfungen. – Mehrfachzählung; in der Regel erwirbt jeder Absolvent die Lehrbefähigung für zwei Unterrichtsfächer.

SOURCE: Received from the First Secretary, Embassy of the Federal Republic of Germany.

APPENDIX 7

TABLE 8



Estimated transfers to different schools or training programs

Graduate of:	*Academic or professional career*	*Vocational full-time schools*	*Training in firms*	*Other—federal defense*	*Other—miscellaneous*	*Total*
Basic schools or special schools	0.0%	10.8%	64.3%	1.6%	23.3%	100.0%
Modern secondary schools—intermediate degree	0.0	23.5	66.7	1.9	8.0	100.0
Gymnasium or other institutions—matriculation examination	89.2	2.5	5.8	2.5	0.0	100.0

Source: Kühlewind, Mertens, and Tessaring, 1975.

SOURCE: von Dohnanyi, Klaus. Education and Youth in the Federal Republic of Germany. p. 22.

APPENDIX 8

Science and Engineering Degrees Awarded in the U.S., U.S.S.R., Japan, and West Germany, As Available, 1976, 1979, 1980

TABLE 9a — 1979 Science and Engineering Graduates: United States and the Soviet Union

TABLE 9b -- [U.S. and U.S.S.R.] Earned Degrees in 1979: Training of Engineers, Technicians, and Skilled Workers (Excluding Adult Education)

TABLE 10 — 1976-1979-1980: Engineering Degrees Awarded for All Countries Discussed

TABLE 9a

1979 Science and Engineering Graduates: United States and the Soviet Union [a]

	Total All Fields	S&E Graduates	S&E Graduates As Percent of Total [b]	Physical, Life Sci. & Mathematics	Engi.	Agri.
U.S.	1,000,600	179,700	17.9%	93,600	62,800	23,200
U.S.S.R.	790,000	416,900	32.9%	49,800	306,800	60,300

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[a] Received from SRI International during telephone conversation with a staff member on Oct. 27, 1981.

[b] Calculated from columns 1 and 2.

TABLE 9b

EARNED DEGREES IN 1979
TRAINING OF ENGINEERS, TECHNICIANS, AND SKILLED WORKERS
(EXCLUDING ADULT EDUCATION)

In thousands

	USA	USSR	
Doctors in Engineering	2.5	(approx.) 12.0	Candidates in Engineering
Masters	16.2	401.7	Diploma Engineers (Graduates of Higher Technical Institutes)
Bachelors	53.7		[No corresponding degree]
[No corresponding training]		779.6	White-collar Technicians, Graduates of Secondary Specialized Schools (Equivalent of 2-3 years of U.S. Technical Institute)
[No corresponding training]		1,103.0	Skilled Technical Workers, Graduates of Technical Schools and Secondary Technical-Vocational Schools
Associate Degrees in Science and Engineering-Related Curricula (Junior Colleges)	103.7		[No corresponding training]
Graduates of Technical-Vocational High Schools	?	1,234.0	Skilled Workers, Graduates of "mass" Technical-Vocational Schools
Trade and Industrial Programs in High Schools	?		

SOURCE: Dr. Izaak Wirszup, Dept. of Mathematics, The University of Chicago, 1981.

TABLE 10

1976-1979-1980
Engineering Degrees Awarded
For All Countries Discussed a/

1976

	Bach. Degree	Master Degree	Doctor Degree	Post-Graduate	Total	Percent of Total Population
U.S. b/	38,774	16,021	2,791		57,586	0.027
W. GERMANY	11,241			8,058	19,299	0.03
JAPAN	68,126			6,216	74,342	0.067
U.S.S.R.	N.A.			N.A.	280,400 c/	1.09

1979

	Bach. Degree	Master Degree	Doctor Degree	Total	Percent of Total Population
U.S. d/	62,375	15,495	2,506	80,376	0.037
W. GERMANY	N.A.			N.A.	N.A.
JAPAN	N.A.			N.A.	N.A.
U.S.S.R.	N.A.			306,800 c/	1.16

TABLE 10 (cont.)

1980

	Assoc. Degree	Bach. Degree	Master Degree	Doctor Degree	Total		Percent of Total Population f/
U.S. d/	N.A.	68,893	16,243	2,507	87,643		0.038
W. GERMANY	N.A.	N.A.	N.A.	N.A.	22,400	e/	0.036
JAPAN	15,012	73,468	7,135	657	96,272	a/	0.082
U.S.S.R.	N.A.	N.A.	N.A.	N.A.	319,800	c/	1.2

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a/ UNESCO Statistical Yearbook, 1978-79, unless otherwise noted.

b/ Vetter, Betty, and Eleanor Babco. Professional Women and Minorities, p. 139.

c/ Received from SRI International during telephone conversations with a staff member on Oct. 27 and 28, 1981, and Apr. 28, 1982, respectively.

d/ Received from the National Center for Educational Statistics during a telephone conversation with a staff member on Oct. 19, 1981.

e/ Received from the American Society of Engineering Education during a telephone conversation with a spokesman on Apr. 28, 1982.

f/ Calculated by CRS.

APPENDIX 9

TABLE 11

1976 Science and Engineering Graduates: All Countries Discussed a/

	Total, All Fields	S&E Graduates	S&E Graduates As Percent of Total b/	Physical, Life Sci., and Mathematics	Engi.	Agri.
U.S. c/	997,500	164,400	16.5%	98,200	46,700	19,500
W. GERMANY	207,719	71,659	34.5%	49,738	19,357	2,564
JAPAN	504,638	133,561	26.5%	30,182	89,673	13,706
U.S.S.R. c/	734,600	383,400	52.2%	46,300	280,400	56,700

N.A. indicates that data is not available.

a/ UNESCO Statistical Yearbook, 1978-1979. Unless otherwise noted. Data only available for 1976.

b/ Calculated from columns 1 and 2.

c/ Received from SRI International during telephone conversation with staff member on Oct. 27 and 28, 1981.

APPENDIX 10

TABLE 12

Projected Market For Scientists and Engineers in 1990 by Field and Level of Training

(all scenarios)

	Baccalaureates and Masters	*Doctorates*
Physical Sciences	Adequate	Adequate
Atmospheric	Balance	
Chemical	Adequate	
Geological	Adequate	
Physics and Astronomy	Adequate	
Engineering	Adequate	Uncertain
Aeronautical	Balance-Shortage[1]	(Possible shortages some fields)
Chemical	Adequate	
Civil	Adequate	
Electrical	Adequate	
Industrial	Shortage	
Mechanical	Adequate	
Metallurgical	Adequate	
Mining	Adequate	
Petroleum	Balance	
Other	Adequate	
Mathematical Sciences	Adequate	Adequate
Mathematicians	Adequate	
Statisticians	Shortage	
Computer Professions	Shortage	Shortage
Life Sciences	Adequate	Adequate
Agricultural	Adequate	Adequate
Biological	Adequate	Adequate
Social Sciences	Adequate	Adequate
Psychologists	Adequate	
Other	Adequate	
All Fields	Adequate	Adequate

[1] Shortage under expanded defense spending assumption only.

NOTE: "Adequate" indicates that projected supply exceeds projected demand. "Balance" indicates that projected supply is close to projected demand. "Shortage" indicates that projected supply is less than projected demand. "Uncertain" is used for doctoral engineers because NSF projects an adequate supply in 1990 whereas BLS projects a shortage in 1985.

SOURCES: Bureau of Labor Statistics, National Center for Education Statistics, and National Science Foundation.

SOURCE: National Science Foundation and Dept. of Education. Science and Engineering Education for the 1980's and Beyond, p. 26.

APPENDIX 11

TABLE 13

PROJECTIONS OF USSR GRADUATIONS FROM HIGHER EDUCATIONAL INSTITUTIONS: 1980 through 1990
(In Thousands)

		Graduations									
		Total, All Fields		Total, Science & Engineering		Physical & Life Sciences & Mathematics		Engineering		Agriculture	
Year	23-Year-Old Population	Variant A	Variant B	Variant A	Variant B	Variant A	Variant B	Variant A	Variant B	Variant A	Variant B
1980	4871	809.3	807.6	430.3	426.8	51.3	50.7	316.9	310.8	62.1	61.4
1981	5000	828.3	829.0	441.9	436.0	52.6	52.0	325.8	319.0	63.5	63.0
1982	5090	847.3	843.9	453.5	443.8	53.8	52.9	334.7	324.7	65.0	64.1
1983	5169	866.3	857.0	465.1	450.7	55.1	53.8	343.6	329.8	66.5	65.1
1984	5151	885.4	854.0	476.8	449.2	56.3	53.6	352.5	328.6	67.9	64.9
1985	4964	904.4	823.0	488.4	432.9	57.6	51.6	361.4	316.7	69.4	62.5
1986	4752	923.4	787.9	500.0	414.4	58.8	49.4	370.4	303.2	70.9	59.9
1987	4512	942.4	748.1	511.7	393.4	60.1	46.9	379.3	287.9	72.3	56.9
1988	4249	961.4	704.5	523.3	370.5	61.3	44.2	388.2	271.1	73.8	53.5
1989	4123	980.4	683.6	534.9	359.5	62.6	42.9	397.1	263.0	75.3	51.9
1990	4041	999.4	670.0	546.6	352.4	63.8	42.0	406.0	257.8	76.8	50.9

Note: Variant A projections based on 1975 through 1979 data contained in Chapter IV, Table IV-9, using least-square linear regression; Variant B projections use the average percentage of the 23-year-old population in the respective fields for 1975 - 1979 as shown in Table IV-9.

Source: USSR population estimates for July 1 of each year, prepared in March 1977 by the Foreign Demographic Analysis Division, U.S. Bureau of the Census.

SOURCE: Ailes, Catherine P. and Francis W. Rushing. The Science Race, p. 188.

APPENDIX 12

TABLE 14

PROJECTIONS OF USSR CANDIDATE OF SCIENCE AND DOCTOR OF SCIENCE DEGREES AWARDED: 1979, 1985 and 1990
(In Thousands)

Candidate of Science Degrees	Total, All Fields	Total, Science & Engineering	Physical & Life Sciences & Mathematics	Engineering	Agriculture
1979	27.8	20.8	7.8	11.5	1.6
1985	26.3	19.7	7.4	10.8	1.5
1990	26.4	19.7	7.4	10.9	1.5
Doctor of Science Degrees					
1979	4.9	3.7	1.4	2.0	.3
1985	7.9	5.9	2.2	3.3	.4
1990	9.5	7.1	2.7	3.9	.5

Sources: Total Candidate and total Doctor degree projections from Soviet Professional, Scientific, and Technical Manpower, DIA, May 11, 1979, p. 99; breakdowns by field of science based on aspirant enrollment percentages for 1974, shown in Chapter V, Table V-1.

SOURCE: Ailes, Catherine P. and Francis W. Rushing. The Science Race, p. 190.

APPENDIX 13

TABLE 15 -- Effect of Engineer and Scientist Shortage on DOD

TABLE 16 — [Engineer and Scientist Shortage:] Impact on Defense Industries

TABLE 17 — [Engineer and Scientist Shortage:] Impacts on the Air Force

SOURCE: Jack Gansler. Shortages of Engineers and Scientists. The Analytic Sciences Corporation (TASC). (Unpublished.)

TABLE 15

EFFECT OF ENGINEER AND SCIENTIST SHORTAGE ON DOD

- DECREASED MILITARY PREPAREDNESS
- INCREASED COST OF WEAPONS (DESIGN)
- REDUCED PRODUCTIVITY (PRODUCTION)
- DIMINISHED INNOVATIVENESS

TABLE 16

IMPACT ON DEFENSE INDUSTRIES

- BETWEEN 25% - 35% OF ALL U.S. ENGINEERS AND SCIENTISTS ARE SUPPORTED BY DEFENSE WORK.
- SHORTAGES DISCOURAGE SMALLER COMPANIES FROM BIDDING ON DEFENSE CONTRACTS AND LENGTHENS SUPPLIER LEAD TIMES
- REDUCTION IN INNOVATION (PATENTS GRANTED TO U.S. CITIZENS DOWN 27% IN LAST 10 YEARS)
- INCREASED SALARIES AND TURNOVER CAUSE INCREASED COSTS (COMPUTER SCIENTIST STARTING SALARIES $30,000 - $35,000)
- IT TAKES INDUSTRIES PARTICIPATING IN VLSI PROGRAM THREE YEARS TO PREPARE NEW ENGINEERS TO WORK COST EFFECTIVELY

TABLE 17

IMPACTS ON THE AIR FORCE

"WE HAVE STARTED TECHNOLOGY PROGRAMS IN THE SPACE COUNTERMEASURES ARENA WHICH REQUIRE 15 ADDITIONAL TECHNICAL PEOPLE -- WE HAVE ONLY BEEN ABLE TO ASSIGN ONE.'

"AFLC ATTEMPTED TO CONTRACT OUT 264 MINUTEMAN MISSILE CIRCUIT BOARDS -- NO BIDS WERE RECEIVED. THE WORK HAD TO BE SCHEDULED IN-HOUSE, BUT, BECAUSE OF ENGINEER SHORTAGES, THE WORK WILL TAKE THREE YEARS VERSUS THE ORIGINALLY SCHEDULED TWC YEARS."

"IN ANOTHER INSTANCE, AFLC LACKED THE ENGINEERING MANPOWER TO PROMPTLY IDENTIFY THE NEED TO CORRECT DAMAGE LEFT AFTER PYLON HOLE REWORK. WINGS ON THREE AIRCRAFT HAD TO BE RESKINNED -- AT A COST OF $600,000."

GENERAL ROBERT T. MARSH
COMMANDER, AIR FORCE SYSTEMS COMMAND

APPENDIX 14

Evaluations of Eleven NSF Science Education Programs

SOURCE: NSF Office of Program Integration.

Title: A Longitudinal Study of Man: A Course of Study (5 vols.).

Purpose: The aims of the two-year study of Man: A Course of Study (MACOS) were to examine the impact of the MACOS curriculum on what students learn, what they retain, and how what was learned was different from what they might have learned otherwise.

Summary

MACOS was one of the more elaborate developments of the "new social studies" projects of the 1960s and was originally designed as a one-year course for upper elementary children. It appeared to combine the content and methods of behavioral science with a humanistic orientation towards education.

The curriculum provides the opportunity for information to be obtained in many ways, e.g., from written materials, films, records, games, and discussions. It encourages students to learn together and to interact with each other, it encourages teachers to take a problem-solving role rather than a lecture or question-answer-question approach to teaching, and it encourages multiple approaches to the presentation of topics so that teachers can adapt to the various interests and abilities of their students.

The present two-year study was undertaken to examine the effectiveness of MACOS with respect to achievement and motivation and sought to explore what teachers and students see themselves as doing in MACOS, and why. The study was primarily descriptive, attempting to delineate a number of similarities and differences of MACOS, compared to a variety of programs that students might otherwise have had.

A number of evaluative methods were used including achievement and attitude measures, interviews of students and teachers, analysis of random samples from tape recordings of classes, rating scales of teacher and student activities and interest, and group discussions with classes.

MACOS lessons were found to have been used quite variably by different teachers; some used MACOS intact, others used as little as 16% of it. Though the diversity of implementation weakens the conclusions that can be drawn, it was found that on generalized tests of social studies skills, taking MACOS neither helped nor hindered average class scores, and that MACOS classes in general did not stimulate confidence in the powers of one's mind significantly more than the aggregate of non-MACOS classes. There was marginal indication that students in MACOS classes tended to react more positively toward people who might have unusual customs or beliefs than those in non-MACOS classes when tested a year later.

During the course, MACOS classes scored significantly higher than non-MACOS classes on three measures of attitude toward social studies. The following year, former MACOS students found their present social studies program less interesting than did former non-MACOS students. Many other comparisons were made and, while there were significant differences between the MACOS and non-MACOS groups of classes for some classroom process (what was done), climate (what students thought of classes), posttest and follow-up variables, there was no variable on which all MACOS classes were better or worse, higher or lower, more or less, than all non-MACOS classes.

Title: Evaluation of the PLATO IV Computer-based Education System in the Community College, Richard T. Murphy and Lola Rhea Appel, ETS, 1977.

Purpose: The primary purpose of PLATO (Programmed Logic for Automated Teaching Operations) is to deliver instruction to students in an interactive manner through the use of student terminals located at sites at varying distances from the central computer. This report provides a description of the implementation and demonstration at the community college level and an evaluation of the educational effectiveness of the PLATO system in terms of its impact on participating students, instructors, and colleges.

Summary

Based on the data collected in the community college project, the PLATO computer-based education system was implemented and demonstrated essentially as had been projected in the initial plans of the developers. Based on the analyses of data collected in 162 classes across the five targeted subject areas of accounting, biology, chemistry, English, and mathematics, in four community colleges, and in the two semesters (Fall 1975 and Spring 1976), the PLATO system provided a medium for instruction with substantial appeal to both students and instructors. The PLATO system had no consistent positive or negative effects on student achievement or attrition. The cooperative effort between instructors and developers was successful in that a substantial number of PLATO lessons were designed, developed, and integrated into ongoing community college courses in the five targeted subject areas. The usage of PLATO by students and instructors exceeded the initial expectations of the developers although the extent of usage in classes was somewhat less on the average than had been projected originally. Based on the personal insights of the evaluators, the critical factor which accounted for the high acceptance and usage of PLATO was the control that instructors had, and perceived that they had, over the use of the system.

Title: Evaluation of the TICCIT Computer-Assisted Instructional System in the Community College, Donald L. Alderman, ETS, 1978.

Purpose: The MITRE Corporation proposed to develop a small computer system which would be dedicated to supporting instruction within a school. Their TICCIT (Time-shared, Interactive, Computer-Controlled Information Television) program was to bring the cost of computer-assisted instruction down to an affordable level for most schools and thus encourage the mass dissemination of computer-assisted instruction by private industry.

Summary

This evaluation covers the results of a demonstration of the TICCIT program at two community colleges. It contrasts the performance of students in classes taught primarily by computer with the performance of similar students from lecture-discussion sections of the same courses. Comparisons focused on four aspects of student performance: course completion rates, student achievement, student attitudes, and student activities. The evaluation also documents faculty acceptance of the TICCIT program and examines the role of teachers in courses where the primary instructional resource was the computer.

After several academic terms of experience with the TICCIT system, faculty expressed uncertainty that the TICCIT program had positively affected instructor duties. Instructors had become less certain that computer-assisted instruction, particularly the TICCIT program, would benefit them in fulfilling their instructional responsibilities. Moreover, those instructors closely associated with the TICCIT project often reacted to the program less favorably than their colleagues in other departments.

The results of this evaluation suggest that the TICCIT program may be inappropriate for community colleges. Only those students strong in their initial familiarity with the subject matter benefited substantially from courses offered under the TICCIT system or derived less benefit from exposure to the program. The strongest argument for a continuation of applications at community colleges would be a counterexample to the course completion rates observed in this evaluation. At institutions with a more select and less heterogeneous student population or with compulsory attendance in instructional programs, the TICCIT program could lead to uniform, positive results.

Title: The PLATO Elementary Demonstration Educational Outcome Evaluation, Spencer Swinton et al, ETS, 1978.

Purpose: The document reports the results of a five-year evaluation of the Elementary Education Demonstration of the PLATO computer-based instructional system.

Summary

The developers of PLATO placed terminals and ancillary devices in elementary classrooms in the Champaign-Urbana area. Two groups of curriculum developers prepared lessons in beginning reading for children from kindergarten to grade two and in mathematics for children in grades four to six.

Two major findings emerged from this evaluation:

1. The PLATO Elementary Mathematics Curriculum was a clear success when delivered in an "add on" mode, and was particularly successful when integrated with teacher mathematics coverage. The PLATO system demonstrated that it was capable of teaching, as well as of providing drill and practice of concepts already introduced by classroom teachers.

2. The PLATO Elementary Reading Curriculum demonstrated negative impact on first-grade reading achievement in the pilot year and on kindergarten reading readiness achievement in the first semester of the demonstration year. No effect on attitudes toward reading was found.

In addition to the principal findings, one conclusion is offered.

> Teachers and students were quite positive about PLATO and its potential. Evaluators concurred that the medium is attractive, flexible, highly interactive, and offers immediate feedback to lesson authors. The evaluators recommend support of such use. However, without considerable cost reduction, PLATO IV does not appear to be an economically viable delivery system for elementary schools.

Title: An Impact Analysis of Sponsored Projects to Increase the Participation of Women in Careers in Science and Technology.

Purpose: To evaluate and assess the impact of 12 experimental projects designed to increase the number of women pursuing science-related careers.

Summary

The methodology used to conduct the evaluation included assessment of project documents, site visits, a participant impact survey, and an evaluation form completed by both the contractor and the project directors. Some difficulty was encountered in conducting the evaluation because of the many different internal evaluation instruments developed and used by the projects. In addition, the design of some of the internal evaluations was not adequate to permit definitive conclusions.

The report contains a synopsis of each of the projects. Each synopsis includes a description of the project as it was originally conceived, the project as it was actually implemented, obstacles to project implementation, a description of project personnel including role models, a report of the primary outcomes described in project documents, the data obtained by the participant impact survey, and observations derived from the site visits. Each synopsis also contains a section on the secondary impacts of the project, the materials developed as the project product, and the dissemination strategies employed by project personnel. Finally, there is a discussion of project costs, including the estimated cost to reuse the curriculum products in other settings.

Given the emphasis on professional careers in science, it was suggested that concentration on high-ability women is a realistic program restriction. It was also recommended that a distinction should be made between career education and programs to interest women in science-related careers.

The general conclusion of the study was that recruitment and commitment should be emphasized in high school years; reinforcement, support and retention emphasized in the college years; and that removing institutional barriers should be emphasized in graduate school, reentry programs for mature women, and post-employment programs. Most of the participants felt strongly that all-female workshops and classes were necessary under certain conditions.

Role models appeared to be the most effective component of most of the projects. It was recommended that role models close in age and accomplishment level to the participants be utilized in conjunction with inspirational models, successful women at the top of their fields. It was also suggested that reentry programs might be more successful in recruiting underemployed, rather than unemployed, women.

Title: An Analysis of Supported Projects to Test Methods for Increasing the Access of Ethnic Minority Students to Careers in Science and Technology.

Purpose: The goals of the evaluation were threefold: to document the experience of the several projects in order to make that experience available to future efforts; to weigh the potential of each project's intervention strategy for more general application; and, to recommend to NSF both policy and administrative changes which would improve procedures for the evaluation of new experimental project proposals.

Summary

The work was comprised of two parallel initiatives. One involved the attempt to provide a context for the individual intervention efforts by examining the experience of a wide variety of other projects and collecting background information related to the typical educational outcomes of minority students as they proceeded through their schooling. The other effort was the documentation of the individual projects and included visits to the project sites and extensive interviewing of both staff and participants.

The report included detailed case studies of all eleven projects and also brought together information from a wide variety of sources related to the educational experience of White Americans, Black Americans, Mexican Americans, native Americans, and mainland Puerto Ricans. "Typical Education Flow Pattern" diagrams summarized the various groups' experience from first grade through graduate school and were utilized to compare retention rates among the five groups at various stages of the education flow. A discussion of the major deviations in experience was included along with suggested priorities for remediation.

On the basis of the experience of the eleven projects studied, a number of common problems were cited including lack of a credible evaluation plan designed to survive potential project implementation difficulties; failure to take advantage of the state-of-the-art of the techniques being considered for use in implementing intervention strategies; lack of recognition that compromises in choosing project participants can change the thrust of the project; and, the need to consider the potential consequences of project failure for all involved.

Policy recommendations dealt with the advisability of expanding experimental programming efforts in the minorities area, the need to increase the participation of minority researchers and institutions in the search for new intervention strategies, and the advisability of NSF assuming more of a role as a resource for the purpose of raising the quality of potential projects. In addition, there were a number of administrative recommendations which could serve to improve the technical level of proposals and increase the probability of success of those experimental projects actually funded.

Title: An Analysis of Ethnic Minority, Women, and Handicapped Student Representation in the Undergraduate Research Participation (URP) and Student Science Training (SST) Grant Programs of the National Science Foundation.

Purpose: To determine the extent to which minority, women, and handicapped students participate in the SST and URP programs and, if those groups are found to be underrepresented, to make ameliorative policy recommendations.

Summary

Telephone interviews were carried out with the Project Directors of a 20% sample of the 133 SST and 169 URP projects active in 1977 which were not specifically aimed at minority or handicapped students. All 18 SST and 12 URP PDs of minority- or handicapped-oriented projects were also scheduled and 26 of the 30 successfully interviewed.

It was found that the participation of handicapped students in the standard projects was very small (5 of 1684 SST and URP students) and the potential pool impossible to determine within the scope of the study. However, the fact that 23 handicapped students were participating in one project in marine biology which was specifically for the handicapped suggested that there are many more handicapped students with interests in other science areas who did not find the standard programs attractive. Women seemed to participate in URP programs in approximate proportion to their presence as science majors in the host departments, but that proportion was somewhat smaller than women's participation in the high school level SST programs.

The number of minority students, was a reasonable proportion of the total in the two programs, but it was found that they participated heavily in a handful of the projects and hardly at all in the others. A number of PD's had actively sought minority participants. Most had simply included minority institutions on their mailing lists and met with very little success, but two URP and several SST PD's recruited and encouraged in person at locations with a high proportion of minority enrollment and had far larger response.

It had been noted that few minority institutions participated in the SST or URP programs and attempts to determine some of the reasons for this failure yielded the following picture: Instructors at minority institutions carry a larger than usual teaching load and thus have less time for individual research, or proposal writing, while there is a clear feeling of discouragement with NSF since there is the impression that SST and URP grants go to the educationally elite institutions, that most of those are renewals, and that there is very strong competition for the relatively few new grants made each year. This last impression was investigated during this analysis and found to be substantially correct: 30% of the SST and 22% of the URP grants were first-time awards; the remaining 44 projects averaged about 7-1/2 years of previous funding.

The recommendations centered around proposed methods for expanding the number of SST and URP client institutions, promoting greater interest among women, minority and handicapped students, and assisting PD's in their efforts to recruit minority participants.

Title: Panel Evaluation of Nineteen Pre-College Curriculum Development Projects, December 8-12, 1975.

Purpose: This report details the efforts of the National Science Foundation to evaluate nineteen pre-college curriculum projects.

Summary

During the week of December 8-12, 1975, 73 people met in Washington, D.C. in seven panels to assist in a review and evaluation of the 19 precollege curriculum development projects currently being supported by the National Science Foundation. This review was responsive to guidance from the Congress and from the National Science Board (NSB), the Foundation's chief policy-making body.

This report documents the reason for the review, its organization, and the reviewers' responsibilities. It also contains the full report of each panel, individual panelists' comments, the perspectives of the directors of the 19 projects, and descriptive material about each project.

Seven panels were formed to perform the review. One panel dealt with each of the areas of: elementary mathematics projects (e.g., Unified Science and Mathematics for Elementary Schools); secondary mathematics projects (e.g., Sourcebook in Applied Mathematics); and social science projects (e.g., Exploring Human Nature). Because of the large amount of material to be covered, three panels dealt with secondary science projects (e.g., Individualized Science Instructional System). The seventh panel consisted of publishers of elementary and secondary school science curricula (e.g., Technology-People-Environment).

The reviews were addressed to several questions, including the following:

- Do a genuine need and market exist for these instructional materials?
- Is the content of the instructional materials scientifically correct and educationally sound?
- Are the proposed and anticipated outcomes of the instructional materials desirable?
- Do these instructional materials present implementation problems for the schools?
- What are the general impressions of the curriculum?

Title: Status Studies of Pre-College Science, Mathematics and Social Science Educational Practices in the U.S. Schools (1978) 7 volumes.

Purpose: These studies were assembled to determine the status and needs of science, mathematics and social studies education in the nation's elementary, junior and senior high schools.

Summary

In 1976, the National Science Foundation funded these three projects, based on different methodological approaches, to investigate the status of science, mathematics and social studies education in American schools. The overriding theme of these studies is that serious attention needs to be paid to improving the quality of precollege science, social studies and mathematics education. However, improving quality is not simply a matter of developing up-to-date curricula, the problem is much more comprehensive than curriculum alone. It involves understanding the critical and essential role that the teacher plays in classroom instruction and in pioneering the development of new instructional materials. It also involves acceptance of the fact that the textbook is central to instruction. Furthermore, it must include consideration of the importance of student motivation and the teacher's need to foster attentiveness and responsiveness in students--even through teaching those skills, if necessary.

Other issues that need to be faced include those of serious preservice shortcomings and in-service training needs; the related problem of the misassignment of teachers and courses; the optimal use of tests and evaluation procedures; and the influence of the overall organizational makeup of the school on precollege education.

Title: What Are the Needs in Precollege Science, Mathematics, and Social Science Education? Views from the Field (1980)

Purpose: The purpose of this publication was to serve as a vehicle to aid in communicating the findings of the status studies to different audiences.

Summary

This document presents a compendium of nine interpretive overviews of the earlier status study publications.

This report suggests a number of strategies to enhance education in science and mathematics at the precollege level. The recommendations that follow are those that appeared most frequently:

1. Federal and state agencies should provide support on a competitive basis to colleges and universities to conduct workshops for lead teachers and supervisors in schools that make commitments to organize subsequent in-service training programs using these personnel. Workshops should focus on subject matter and classroom techniques.

2. Teachers should be central figures in research--but not only as "subjects." They should be partners in the research enterprise. Teachers should be involved to a much greater extent in the process of defining needed research.

3. Efforts are needed to make more effective use of the textbook as a central feature in the education process.

4. A recommended solution to the lack of teacher time is to provide paraprofessional assistants. (Paraprofessionals can perform such duties as setting up and taking down laboratory and demonstration equipment, maintaining storerooms, checking inventories, ordering supplies, preparing reagents, making minor repairs, maintaining equipment, dispensing storeroom supplies to students, and maintaining aquaria, terraria, and animal cages.)

5. A commission should be established to reexamine in depth the goals and purposes of American elementary and secondary education.

6. Greater support is recommended for NSF institutes for teachers, both to increase their knowledge of subject matter and to improve their skill in teaching the new courses that will be developed in the future.

7. The Education Department could earmark funds for state departments of education to award to schools seeking to upgrade science programs in the elementary and junior high schools.

8. It is recommended that efforts should be made to identify gifted economically disadvantaged students early in their schooling, so as to ensure that they will be afforded adequate opportunities to prepare themselves for admission to scientific and technological programs in college.

Title: Oversight and Evaluation of Resource Centers in Science and Engineering: A Progress Report to the Congress (January 1980).

Purpose: The purpose of this report is to provide an evaluation of the Resource Centers for Science and Engineering to find how well the center concept is working and whether the establishment of more centers would be desirable.

Summary

The report gives a brief overview of the center concept and its impact upon students and their teachers at three levels: the precollege, the undergraduate and the graduate level.

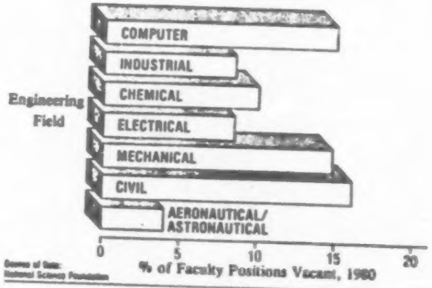
A description of the two existing Resource Centers at Atlanta University and the University of New Mexico/New Mexico State University (Southwest Resource Center) is given. Activities include support of basic research and research facilities/equipment acquisition; serving as a regional resource in science and engineering for the community; and the development of joint educational programs with nearby precollege and undergraduate institutions.

Recommendations are given based on external evaluations, internal evaluations and site visits by some of the Advisory Committee members. Major recommendations are the following:

- It is strongly recommended that the National Science Foundation request funds to implement a minimum network of seven Resource Centers.
- It is recommended that future Resource Centers be at institutions which have or show potential for a strong base on which the Center could be built; evidence of significant involvement of appropriate persons in the development and implementation of the project; and a convincing case that the Resource Center would make a difference at the institution and in the region.
- It is recommended that future funding decisions not be delayed by requiring extensive evaluations at this early stage in the development of the center concept so that momentum may be maintained and the center concept fully developed.
- It is recommended that the Advisory Committee for Minority Programs in Science Education be maintained with no fewer than nine members in order to monitor and oversee the Resource Centers as well as other programs.

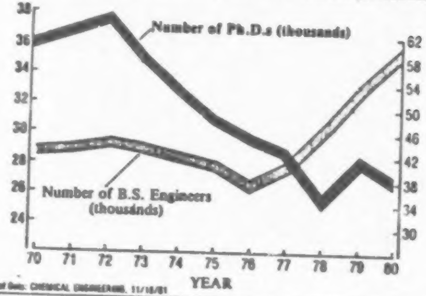
APPENDIX 15

Engineering Faculty Face Serious Shortages



Source of Data: National Science Foundation

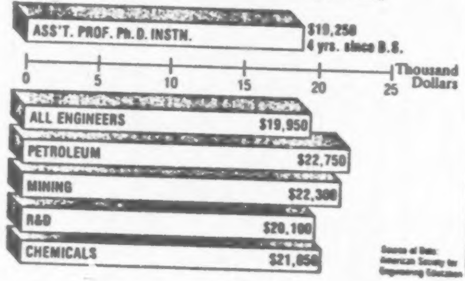
While the number of B.S. Engineers keeps increasing . . . the alarming drop in Ph.D. degrees becomes more pronounced.



Source of Data: CHEMICAL ENGINEERING, 11/16/81

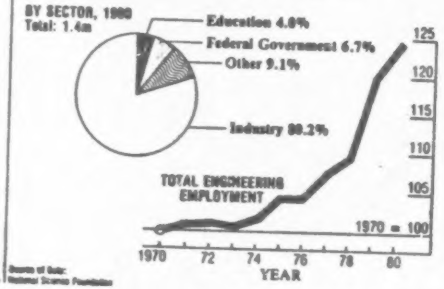
Median Salaries (Mid-1980) for

Assistant Professor 4 years after B.S. Degree VS. Beginning Engineers, by Industry



Source of Data: American Society for Engineering Education

Employing America's Engineers



Source of Data: National Science Foundation

SOURCE: From a compilation of information presented with the testimony of Dr. Edward David, President of the Exxon Research Co., at hearings on H.R. 5254 before the House Committee on Science and Technology, Subcommittee on Science, Research and Technology on April 27, 1982.

APPENDIX 16

TABLE 18

National Science Foundation
Science and Engineering Education Directorate: 485/ Obligations, 486/
Fiscal Years 1952-1983

(In Millions of Dollars)

1952 -- $ 1.5

1953 -- 1.4

1954 -- 1.9

1955 -- 2.1

1956 -- 3.5

1957 -- 14.3

1958 -- 19.2

1959 -- 61.3

1960 -- 63.7

1961 -- 63.4

1962 -- 83.6

1963 -- 98.7

1964 -- 111.2

1965 -- 120.4

1966 -- 124.3

1967 -- 123.4

1968 -- $124.8

1969 -- 106.5

1970 -- 120.2

1971 -- 68.8

1972 -- 93.7

1973 -- 62.2

1974 -- 80.5

1975 -- 74.1

1976 -- 66.1

1977 -- 74.3

1978 -- 73.9

1979 -- 72.4

1980 -- 73.8

1981 -- 70.7

1982 -- 20.9

1983 -- 30.0

485/ The Directorate has been called various names over the years from the Division of Scientific Personnel and Education, to the Directorate of Science Education, to the current title, Science and Engineering Education Directorate.

486/ The figures, which have been rounded, were received through a telephone conversation with a spokesman at NSF on June 20, 1983.